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BAYER LEVERKUSEN (GERMANY)
Department for Crop Protection

Results, problems and trends in the biological development of and research on insecticides, especially organophosphorus compounds*

by G. Unterstenhöfer

The productivity of crops especially those afforded intensive plant protection has shown a marked rise in the last two decades. This has been largely brought about by the advances in direct control of plant diseases and insect pests. The harmonious coordination of the three principal elements of rational control practices, which have been scientifically developed with such great success, viz. the forecasting method, equipment technology and chemical pesticides, raised the efficiency of crop protection measures, increased their profitableness, and thus established the economic prerequisite for an increased intensity of land utilization. This development is most impressively reflected in fruit-farming by a general trend from extensive cultivation of standards as a sideline to the intensive cultivation of bush-tree orchards producing high-grade varieties to meet market demands. Similar trends, although not so striking, are apparent in numerous other sections of land utilization. An exact analysis of this situation leads to the conclusion that the impetus behind this trend stemmed from the successes that can be claimed by research workers engaged on the development of active ingredients, especially in the sphere of insecticides. This research resulted in an unforeseen increase of efficiency which justifies the statement that today there is hardly a major insect pest in existence which cannot be controlled by economic methods. Compared with insecticides, the development of new fungicides has proceeded much more slowly. Nevertheless, the range of active ingredients is so large that even the most important mycoses can be successfully suppressed. Research on herbicides is progressing with enormous momentum. New active ingredients are being continuously developed for a multitude of uses, thus establishing the technical prequisites for weed control under widely varying conditions.

The outcome of this development is that the decision whether the weight of pest control should rest in future on biological or chemical methods, has now been taken by agriculturists in favour of chemical pest control. According to our present level of knowledge, this decision best of all makes allowance for the only too often overlooked elementary fact that most cultivated plants are not natural species but constitute one-sided, highly bred elements which originally were foreign to our flora. Hence, an organic, self-preserving "equilibrium"

* Paper presented in Moscow: 21. 7. 1961

of the society to which they belong, built up on biological measures, appears doubtful from the very outset. Biological pest control in the narrow sense would only be useful in agriculture if it were to suppress all noxious organisms at the same time. This requirement, however, cannot be fulfilled according to the present state in intensive agriculture. Considerations in forestry which by nature entails extensive practices, follow a completely different line. In that field, there is an inclination towards biological measures in the broader sense.

All views and opinions put forward in this paper on the results, problems and trends in the development of and research on insecticides, especially insofar as they belong to the group of organophorus compounds, are expressed from the technical development and biological aspects, and not from the chemical standpoint. This means that in the first place the general biological problems are regarded as the essential content of the representation, and are placed in the foreground because in the end they dictate the direction of work in this aimed research. In the discussion of individual active ingredients, the special nature of the problem is given prominence over the general question. Considered under these aspects, the present situation in the field of insecticides can be very precisely outlined in broad terms confined to the essential points. For it is comprehensible that the synthetic insecticides which, with respect to their potency, are so important, have been intensively studied from both the scientific and the practical aspect, and that in doing so one has become closely familiar with the different active ingredients with regard to their activity, after-effects and side-effects.

The modern synthetic insecticides are mainly classified in two groups: the chlorinated hydrocarbons (including dichlorodiphenyltrichloroethane and related compounds, lindane and the Diels-Alder dienes), and the organophosphorus compounds. Besides these are other smaller, less important or less kown groups, of which the carbamates will be mentioned.

In general usage, synthetic insecticides are widely referred to as contact poisons, thus underlining a property common to all these active ingredients which chemically are so different; namely, the power to unfold their toxicity after resorption through the cuticle and the resorption points situated there, which are predestined for uptake of active ingredient. But it must be borne in mind that percutaneous uptake is not the only mode of entry into the organism, and that oral uptake and respiratory uptake also occur as a rule, and may in fact excel the contact action.

A further characteristic of undoubtedly all synthetic insecticides with respect to control technique is that they have a time-dependent toxic action as opposed to the timeless toxic action which, for example, is characteristic of arsenic. With this form of action, the toxic effect is determined by the dosage and the time, and is also dependent to a certain degree upon temperature in that rising temperatures may accelerate (positive temperature coefficient) the effect, e.g. dichlorodiphenyltrichloroethane.

Even though the synthetic insecticides have the common property of a percutaneous and time-dependent toxic action, there are nevertheless marked differences in the spectrum of activity and in the after-effects and side-effects both among the various groups as well as among the different active ingredients. Each active ingredient has its own toxicological characteristics peculiar

only to itself. These do not become known until after thorough testing, which means that they cannot be deduced, not even approximately, from the chemical constitution with such reliability that could lay claim to being constructive for chemical research on active ingredients — although such knowledge would naturally be very desirable. The explanation for the fact that only the biological experiment can give a definite answer to the manifold questions lies in the species-specific, stage-specific and strain-specific behaviour of the world of organisms, for which a causal explanation has not yet been found.

This, in conjunction with the empirical fact that for all properties which make a chemical suitable as an insecticide to be combined in one molecule is no more than slightly probable and, if it were to happen, may be regarded as most fortuitous in the statistical sense, characterizes the development of new active ingredients — the discovery of new active ingredients is a genuine probability problem. In view of these facts, it is obvious that even the probability of discovering new active ingredients which constitute a real advance is all the less the higher the level of technology. For this reason, large steps forward in the field of insecticides are only to be expected provided extensive chemical and biological research is in progress. Furthermore, the higher the standard of efficiency of the preparations the more difficult it will be to distinguish between innovations and technical advances, added to which more intimate knowledge will be required of the nature of the biological, economic and technical problems for which solutions are sought. For after all, such knowledge provides the criteria for the selection of active ingredients.

Although the standard of technology in the field of insecticides is high, there is nevertheless a real necessity for continued efforts. The reason for this is twofold; firstly, every active ingredient has one or the other property which indicates the need to search for an improvement, and secondly the problems of pest control are constantly changing in keeping with the continous development of land utilization. There are mainly two problems which are brought about by pest control and cultural practices, and which do not permit a predictory assessment to be made, thus making it necessary to find replacements for already available products — change of species ascendancy and resistance to insecticides.

Changes in the environment lead to changes in the "society". The latter are termed successions. The use of insecticides also means a change in the environment, which results in the mentioned change of species ascendancy. This is manifested by major pests losing importance and being reduced to very small numbers in the course of time as the result of intensive controls. Consequently they relinquish their ascendancy, and their place is taken by species which hitherto have only been of secondary importance, either because the applied active ingredients are less effective against these newly dominating species or else they occur at a time when no control programmes are carried out. Such changes in the fauna are continually observed in intensive crops so that the pest generation undergoes a transformation in time. When these fluctuations in the pest fauna are studied, for example, in modern, intensively managed orchards, it becomes clear that every new control or cultural practice is followed in time by a change in the pest fauna — major pests disappear, and secondary species take their place. The further this process progresses, the more necessary it

becomes to concentrate on the task of developing substances with different spectra of activity adapted to the new situation.

This "change of species ascendancy" is not a problem brought about only by chemical pest control programmes; on the contrary, it can just as easily be caused by any other cultural practice insofar as it involves a change in the environment, no matter how slight. It is known, for example, from exact studies that the weed species which we have to deal with today in arable farming, at least in some areas, are different from those that occurred a century ago, due to the changed agricultural practices.

Besides the "change of species ascendancy", resistance to insecticides is the main reason for having to develop new active ingredients. Resistance to insecticides is understood, as we know, to mean that active ingredients which could be successfully used against a certain pest for a greater or lesser period, progressively become less effective until they are eventually useless for control purposes. An originally susceptible insect species has, therefore, become resistant to an insecticide or, in other words, now tolerates it. Like the "change of species ascendancy", resistance to insecticides also makes it necessary to develop new active ingredients which, however, in this latter case — at any rate, as far as we know at present — must belong to new active substance groups that feature completely different mechanisms of action from those previously used. Therefore, resistance to insecticides, in the narrow sense, after all attaches greater weight with regard to the development of new active ingredients than does the "change of species ascendancy" for to counteract the latter phenomenon new active ingredients must be developed which only have a different spectrum of activity but not necessarily a different mechanism of action, so that they can definitely belong to the same active substance group already in use.

Development of resistance, like the change of species ascendancy, also has genuine parallels in non-chemical crop protection practices, in this case in the breeding of resistance. Impressive examples are the collapse of phytophthora- and wart-resistance of potatoes and rust- and loose smut-resistance of wheat. Changes of species ascendancy and development of resistance as processes of adaptation to changed environmental conditions are, therefore, apparently common reactions of nature, on the one hand on the part of the environment, and on the other hand on the part of the species.

Besides these biological-ecological factors, there are also the economic factors which continuously confront the development of active ingredients and their application with new tasks. At present it is chiefly the shortage of labour in agriculture which, to a lesser or greater degree, is responsible for the change in crop protection practices as a whole. For example, this factor has had a great influence on the development of systemic seed dressings and granulates.

Apart from reasons associated with control techniques, economic reasons also influenced the decision whether insecticides with a wide spectrum of activity or products with a selective action should be given preference in the development of new active ingredients. The decision went in favour of polytoxic insecticides. From the technical aspect, that is with regard to controls, the issue was decided firstly by the fact that very often several pest species have to be controlled at the same time, at least on crops requiring intensive protection, and secondly that in many cases no clear diagnoses are made before

control operations are started; the resultant errors have little or no effect when polytoxic products are used. For that matter, effective biological controls which rely especially on the activities of predators are not selective, either (protection of birds, ants). From the economic aspect, the greatly simplified question of storage decided the issue. With active ingredients that have many uses, any changes of the 'control targets', that is a shift of emphasis from one species to another, that may take place from year to year, will not have any effect on one's dispositions. When insecticides that have a wide spectrum of activity are purchased (and there is a big demand for these products because of this property), there is less danger of capital being tied up for unnecessarily long periods without realising any returns, than is the case with selective active ingredients which cannot be used so often.

These briefly outlined facts and considerations, that have decisive bearing on product research, led to the formulation of the subject under discussion: Pest control with chemical products must be constantly re-adapted to new conditions. As the outcome of biological-ecological and economic development processes we are continually confronted by new tasks or changes of 'control targets', i.e. a shift of emphasis from one species to another; in consequence, new products are needed or are at least desirable. The development trends are governed by problems which, in turn, frequently arise from results.

It has already been said that the most important insecticides in use belong to the groups of chlorinated hydrocarbons and organophosphorus compounds. Of these, attention will be chiefly focused in this paper on the organic phosphates.

In our company, we have worked very intensively on the chemical and biological development of organophosphorus compounds, especially as pesticides. Following the publication of the chemical studies and the results of the biological research on the insecticidal and acaricidal potencies of the active ingredients of this group, intensive chemical and biological research began throughout the world because it was recognized that work on this field which borders between inorganic and organic chemistry, and which hitherto had received little attention, would prove extremely fruitful especially for the development of new insecticides. It is due to this intensive research work that we now have a clear picture of the most important properties of the active ingredients so far known, a picture the like of which does not exist for any other group of active ingredients. Today, some ten organophosphorus compounds are in practical use. Although they often differ most considerably in their chemical constitution, they nevertheless possess a few chemical and biological-physiological properties that are common to them all. For example, the known biologically active phosphates are based on a uniform structural pattern which today also generally serves as the working hypothesis for discovering new active ingredients. The correctness of this knowledge has been confirmed in the testing of thousands of compounds. In view of this, it is comprehensible that the mechanism of action, in the sense of the primary point of attack in the organism during the toxic process, is also to be regarded as being very similar among the effective phosphates, a finding strongly substantiated by experiments. It is based on the inhibition of a group of esterases, in general, and the cholinesterase, in particular. There is no other group of insecticidally active compounds with which we are by any means as closely familiar as we are with the phosphoric esters. Toxicological discussions are thus made easy

and assume complete accuracy because the intimate knowledge of the mechanism of action has led to conceptions of possible hazards that are just as clear as those of prophylactic and therapeutic measures. Perhaps the best additional proof of the correctness of the statement that a uniform mechanism of action exists is provided by the fact that atropine and PAM (pyridine-2-aldoxime-methiodide) can be used with full success as antidotes for all known phosphoric esters.

The mechanism of action against insects and mites is also based on an inhibition of esterases, namely the cholinesterases and the aliesterases. On the one hand, the esterases which cleave methyl butyral (flies, cockroaches) are inhibited more, and on the other hand those which cleave triacetin (Aphidae, Tetranychidae). Apparently it is more difficult to explain the mechanism of action for arthropods than for mammals.

Despite the very uniform mode of action of the insecticides in this group, the spectrum of activity (with marked polytoxicity as the one extreme and well-defined selectivity as the other extreme) and the toxicological characteristics (initial toxicity, concentration level, resorption route) differ very largely from one product to another. Organophosphorus compounds continue to provide active ingredients for practically all purposes of pest control. The active ingredients can be so selected that they satisfy not only the requirements of crop protection but also those of public health and veterinary medicine.

On the basis of very comprehensive test material, it has been possible to formulate a rule with a wide range of validity, which appears to be of importance for the assessment of organophosphorus compounds:

> A wide spectrum of insecticidal activity is always linked with increased mammalian toxicity, and selectivity with low mammalian toxicity.

This correlation always applies only within a certain dosage range for each active ingredient. The dosages for the characterization of the mammalian toxicity are always expressed in absolute values, while for the spectrum of insecticidal activity dosage ranges are chosen the limits of which are fixed by economics factors or by side-effects. For the spectrum of activity, in contrast to efficacy, is always a relative value, because the spectrum widens proportional to the degree in which the dosages are raised.

In the systematic testing of organophosphorus compounds, we established, however, that members with group-specific selectivity can definitely be found in this group, in other words compounds which, with a medium or low order of mammalian toxicity, possess a relatively wide spectrum of insecticidal activity within an otherwise favourable dosage range. In conformity with the aforementioned rule, these compounds, however, also displayed, in contrast to the toxic substances that have a wide spectrum of activity, a more or less pronounced optimum of activity against a certain group of pests. The conclusion was drawn from these findings that it ought to be possible to find a substance of low mammalian toxicity but possessing a wide spectrum of activity, which could be applied as an insecticide for many uses. But it also had to be borne in mind, in view of the many prerequisites that have to be

fulfilled, that in order to discover such an active ingredient it was necessary to have available a very large volume of chemicals. From the biological aspect, well-functioning test models comprising an abundance of species were required.

The main facts that apply to the development and study of insecticides can be summarized as follows:

1. There is no relation between chemical constitution and insecticidal action which one could regard as being technically constructive for the development of new pesticides, and which would allow the extent of chemical and biological work to be reduced.
2. The discovery of new active ingredients is fortuitous in the statistical sense, and as such a function of the number of tested compounds and of the experiment carried out on as many test objects as possible. In this, experience is an essential factor.
3. Change of species ascendancy, development of resistance and economic realities make constant research compulsory.
4. Polytoxic compounds, even though poisonous to mammals, still have priority over selective, non-toxic compounds in crop protection because of the special conditions prevailing in this field. Insecticidal activity and hazard (human safety factors) are values which must be carefully separated.
5. Among the various groups of active ingredients, organic phosphates hold a central position; due to their extremely large abundance of possible variations from the chemical and toxicological-physiological aspect, they provide active ingredients for all purposes of insect and mite control.

Following these general comments, details will now be given especially concerning the results, problems and tendencies with respect to organophosphorus compounds. From the aspect of application, a distinction must be made between two types of active ingredients:

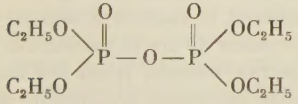
I. Ectotherapeutic insecticides

II. Systemic insecticides and acaricides

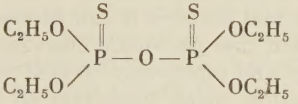
I. Ectotherapeutic insecticides

1. Parathion and its derivatives

It was through TEPP and sulfotepp, which are still used today for special purposes, that the group of organophosphorus compounds began to acquire practical importance.

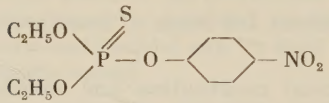


TEPP

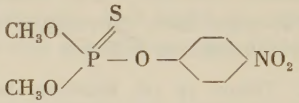


Sulfotepp

They are followed by Parathion and the homologous dimethyl ester. Their discovery was the start of a new era of insect control.



Parathion



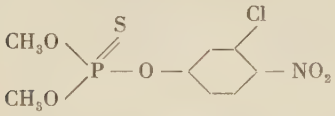
Methylparathion

Parathion, which was synthesized by Schrader in the laboratories of Farbenfabriken BAYER and biologically tested by the research workers of the same company, is still the most prominent member of the ectotherapeutically active phosphoric esters. Parathion has established a standard by which every newly marketed product is still measured even today, fifteen years after the discovery of Parathion — an extremely long period in this fast-moving age. Even though a vast number of publications has already been issued dealing with this product, and Parathion can undoubtedly be termed as the best known insecticide, these very facts nevertheless justify a brief description being given of the properties which have gained this active ingredient its outstanding position because when the abundance of individual results is so great the character of an active ingredient can easily be overlooked:

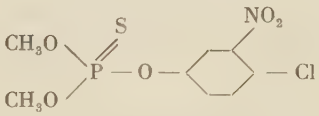
Parathion has an almost universal insecticidal and acaricidal action against biting and sucking species, with a pronounced intensity of activity; its action is only very slightly dependent upon the widely varying conditions that govern toxic effect. It acts as an insecticide, larvicide and ovicide, and need, therefore, only be applied at very long intervals — for example, in fruit-growing during the vegetation season and as an oil formulation in the period of vegetation dormancy. The resorption route is, therefore, nonspecific, because an effect is produced both after percutaneous resorption as well as after oral and respiratory resorption. It has a residual action which, although of limited duration and dependent upon the substrate, is completely adequate for the main uses. The residual action is relatively long on nonbiological surfaces, of medium persistence on fruits, and shorter on foliage. A feature of special importance is its translaminar action, already established by us in the first tests, and later the object of numerous individual studies; this property of being able to penetrate deep into the plant tissue made it possible to eradicate concealed pests, also those not directly hit by the spray, and mining insects. The product also displayed excellent plant tolerance. The combination of all these briefly outlined, excellent properties in one molecule is an extremely rare fortuity, and justifies the use of superlatives even in the description of the product. Parathion is really a unique pesticide. Even the high acute mammalian toxicity, strongly criticised at first and still censured in certain circles, does not detract from this exceptionally high rating. Parathion lacks chronic toxicity, owing to its high insecticidal potency it can be used at low dosages, it is broken down on and in the plant into non-toxic cleavage products, and cases of acute poisoning can be quickly and effectively treated — all these features, viewed from the aspect of application, make Parathion an insecticide which, provided reasonable precautions are observed, is no more hazardous than other insecticides that have a

lower acute toxicity but which possess a high chronic toxicity or are less known as therapeutic products. It is a regrettably unfounded prejudice, which is difficult to stamp out, to regard Parathion and phosphoric esters as highly toxic compounds simply because the easily and quickly determined acute toxicity is used as the criterion, while one continues to underrate the chronic toxicity of many non-phosphorus insecticides, which is not recognised until later and is also considerably more serious.

The properties of Parathion and its behaviour in and on plants and in mammals have been exhaustively studied. It was hoped that the findings which resulted from these studies, would furnish, on the one hand, information regarding the relations between constitution and insecticidal activity, and provide, on the other hand, suggestions for the preparation of still more effective insecticides. That is understandable, for a compound of the importance of Parathion was after all a stimulus to research workers to develop and prepare similar compounds. Of the many analogs of Parathion, only CHLORTHION® and ISO-CHLORTHION® have aroused interest as insecticides.



CHLORTHION
(625 mg/kg)



ISO-CHLORTHION
(1000 mg/kg)

It is interesting to note that the compounds have only slight mammalian toxicity. But their spectrum of activity is most considerably smaller. Both active ingredients confirm the aforementioned rule that low mammalian toxicity is linked with a small spectrum of activity and a specific range of uses which, for CHLORTHION and ISO-CHLORTHION, is restricted to aphids and Diptera.

2. GUSATHION®

The decision to supplement the potencies of Parathion by active ingredients with special properties was prompted by three biological factors: development of resistance, change of species ascendancy, and the desire dictated by the behaviour of various pests to have active ingredients with a residual action based on persistent extracuticular and cuticular residues as opposed to the cuticular and subcuticular residues of Parathion.

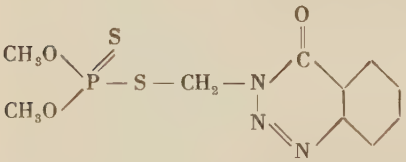
With regard to the development of resistance, an acute case was the Parathion-resistance of spider mites, and especially the resistance of the boll weevil *(Anthonomus grandis)* to chlorinated hydrocarbons. In cotton-growing, however, Parathion did not enjoy unlimited approval because of its short residual action, so that it could not fully replace the chlorinated hydrocarbons. With respect to change of species ascendancy, there is the example of a pest of hitherto secondary importance which gradually became more prominent in recent years in Italian orchards, and for that matter also in other fruit-growing regions, namely the pear sucker *(Psylla pyricola)*. Even though this pest defini-

® = Registered trade-mark of Farbenfabriken Bayer AG, Leverkusen

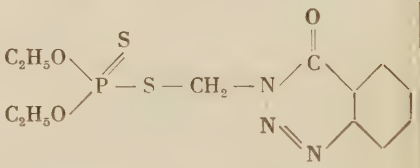
tely reacts to Parathion, it nevertheless proved desirable to develop a product with a longer residual action, which at the same time gives control of resistant spider mites.

Regarding the residual action, it should be mentioned that Parathion has a relatively long residual action on fruits but on foliage its persistence is of very short duration. As a result of this, it became necessary — for controlling certain pests which continue to attack crops for long periods due to a prolonged flight, migration or dispersal in batches, or due to microclimatically controlled, varying embryonic development — to develop an active ingredient that remains effective for a lengthy period on the plant surface, which therefore lacks the translaminar action typical of many phosphoric esters, and which in its properties approaches the persistent chlorinated hydrocarbons. It was required that the compound should again have a wide spectrum of activity because this property is an essential prerequisite for its application in crops needing intensive protection — and it was just here that a genuine need for a new insecticide existed.

We found in GUSATHION an active ingredient which possesses the desired properties in the necessary potency, once again illustrating the extreme wealth of useful substances contained in the group of organic phosphates.



GUSATHION M



GUSATHION A

Like Parathion, GUSATHION also has an ethyl ester and a methyl ester. Both esters, also like those of Parathion, are largely similar in their intensity of action and spectrum of activity, and merely display gradual differences in some uses:

GUSATHION A, for example, has a stronger acaricidal action also against r-mites, while GUSATHION M is more effective against Coleoptera. GUSATHION has an almost universal action. Its most important uses are:

1. Fruit-growing: There is hardly an insecticide which, in efficacy and spectrum of activity, could be compared with GUSATHION for pest control in fruit-growing. In this use it is at least equal to PARATHION, and in fact it has been found that in some orchards treated for many years past with Parathion it is superior to the latter product due to the changes of species and strains in the fauna.

2. Cotton-growing: In comparison tests, the lowest pest infestation figures and the highest crop yields are always obtained in cottonfields treated with GUSATHION.

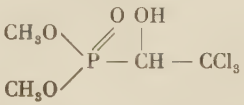
3. Citrus-growing: For the treatment of citrus fruits, GUSATHION shows every promise of becoming a universal insecticide and acaricide on account of its action against scale insects combined with its excellent acaricidal effect and its good aphicidal action.

In its efficacy, GUSATHION is about equal to Parathion. That also applies to its toxicity rating. GUSATHION has very low dermal and respiratory toxicity, and is a product with very slight chronic toxicity.

The contact action and stomach poison action are about the same for GUSATHION; its action in the vapour phase is slight. It has insecticidal, larvicidal and ovicidal potencies. The susceptibility of the different stages is species-specific. Its translaminar effect and systemic action are slight, and attach no importance in normal field application. Its residual action on the plant is considerable, its stability to light, especially to ultraviolet light, is high for a phosphoric ester, and its plant tolerance is very good.

3. DIPTEREX® — NEGUVON®

In the systematic testing of the properties and potencies of organophosphorus compounds, a phosphoric ester with the following structural formula was found to be of extreme interest:



DIPTEREX — NEGUVON

It has very slight mammalian toxicity, and possesses a strong although specific insecticidal action. It is mainly active against Diptera, but also gives control of Lepidoptera and Hymenoptera. The active ingredient is used in crop protection, for controlling house flies, and in veterinary medicine.

DIPTEREX holds a special rank among the organophosphorus compounds because its stomach poison action is almost sixty times greater than its contact action. It also has an unusually marked translaminar action, which at least partly accounts for its good effect against stem borers (e. g. maize stalk borer, *Busseola fusca)* and the beet fly *(Pegomyia hyoscyami* = mangold fly = spinach leaf miner). It should also be mentioned that when the active ingredient is taken up through the roots it acts against biting insects, this having been proved in applications against larvae of diamondback moth *(Plutella maculipennis).* Therefore, DIPTEREX has a systemic action in the broader sense. But it lacks the property of affording long-term immunization that is typical of genuine systemic active ingredients.

Considering that the residual action of DIPTEREX is generally only of short duration, the fact that it is persistent for an appreciably long period on and in beet leaves is all the more remarkable. The reason for this is unknown although the dependence of hydrolysis on the pH probably has something to do with it; after all it is known that the pH range need only shift slightly towards the acid side for stability and persistence to be increased.

In the field of public health, especially for controlling flies, the stomach poison action of the active ingredient is utilized by applying baits to which sugar is usually added. The high initial toxicity or rapidity of action of this compound is especially valuable in the control of flies and fly maggots.

As NEGUVON, the active ingredient is used today in veterinary medicine for controlling larvae of ox warble fly (Hypoderma), against *Dermatobia*

hominis, sarcoptic mange, and as an antihelminticum (*Haemonchus placei, Bunostomum phlebotomum, Cooperia* species). It is also effective against *Trichinella spiralis, Gastrophilus* species, biting lice, other lice and ticks.

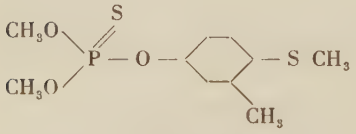
4. LEBAYCID® = BAYTEX®

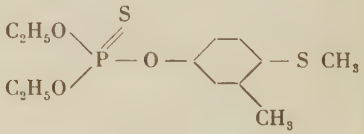
For controlling pests of public health significance, insecticides are needed which are harmless to mammals. But for many purposes in crop protection slight toxicity is also a most desired property as long as it is not a liability to a minimum spectrum of activity or to the economy factor.

Although a wide spectrum of activity is generally linked with high mammalian toxicity, with the result that it was attempted to obtain low mammalian-toxic pesticides with a wide range of uses by combining oligotoxic active ingredients of different activities and which are harmless to mammals, this step can only be regarded as a provisional solution because, as we have already mentioned, the group of organophosphorus compounds also contains substances that have a wide spectrum of activity and yet low toxicity. But these compounds are very few in number and can only be found by empirical means; the task of discovering them, by no means an easy one, was all the more important because the previously described active ingredient DIPTEREX, although highly effective, is not suitable for some uses and certain application methods. Its relatively small spectrum of activity created only a correspondingly small range of possible uses in crop protection. Due to its sensitivity to hydrolysis and alkalies, it was not suitable for controlling flies by the wall spraying method. It was particularly for this use that there was a pressing need for new products because of the resistance developed by mosquitoes and flies to chlorinated hydrocarbons. In veterinary medicine, too, it has only a short residual action, and therefore cannot be universally applied.

In LEBAYCID we have an active ingredient which can be used for crop protection and public health, and probably for veterinary medicine as well.

Just as with all phosphoric esters that we have made accessible, the ethyl ester as well as the methyl ester have been prepared also for LEBAYCID.





LEBAYCID BAYTEX

Although there are no differences in activity, considerable differences in toxicity do exist, however. After taking all aspects into account, we prefer the methyl ester on the grounds of our present level of knowledge. A detailed analysis of its properties produced the following results:

It has a stomach poison action and a contact action of equal strength, thus establishing the first prerequisite for a wide range of action, in that there are no differences of reaction due to varying resorption conditions. The spectrum of activity is astoundingly large. But the dosages are generally higher than for

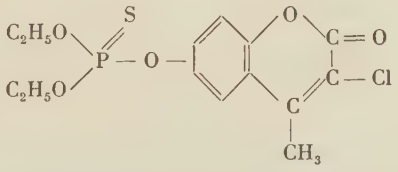
Parathion and GUSATHION, when one disregards the main specific uses which chiefly lie in the control of Diptera. Yet interest still focuses on this product insofar as it represents a genuine advance on Parathion and other active ingredients, that is apart from DIPTEREX in certain respects. This advance is not so much due to the product having an essentially greater effect than DIPTEREX but rathermore to its longer residual action brought about by greater stability to hydrolysis and alkalies and a longer half-life value on plants and on non-biological surfaces. An essential feature of LEBAYCID is its long residual action on fruits (control of olive fruit fly, Mediterranean fruit fly, cherry fruit fly). This property, combined with a marked translaminar action, makes for a long-lasting larvicidal effect in fruits and leaves. On the other hand, the effect against adult flies is relatively short, at all events in crop protection. The stability of the compound to alkalies is especially valuable in the control of house flies and mosquitoes, particularly for producing spray deposits that remain effective for a long time on walls. In this respect LEBAYCID has satisfied a pressing need for an active ingredient with a new mechanism of action, that has existed since house flies and mosquitoes developed resistance to persistent chlorinated hydrocarbons. The activity of LEBAYCID against Diptera has been confirmed in crop protection, in public health and in veterinary medicine.

It has also been found to give good control of aphids, Lepidoptera, Hymenoptera, Heteroptera and Thysanoptera. Its plant tolerance is exceptionally good; it definitely has an acaricidal action although this is not up to the required present-day standard.

Testing of the compound for controlling parasites of veterinary importance has not yet been completed, but there is no doubt that it is excellently suited for control of Diptera, especially blow flies *(Calliphoridae)*.

5. ASUNTOL® = CO-RAL® = MUSCATOX®

Once it became known that house flies, ticks and other arthropods of medical and veterinary importance had developed resistance to chlorinated hydrocarbons, research workers found themselves faced with the urgent task of discovering and developing products from the group of organophosphorus compounds to control these resistant species. In fact, the need for such products became all the more pressing when results of tests with Parathion indicated that house flies in particular might possibly be able to develop slight resistance to phosphoric esters. During the course of this research we found in the active ingredient of ASUNTOL a substance which, although not being suitable for crop protection, was ideally suited for the control of public health and veterinary pests.



3-chloro-4-methyl-7-oxycoumarin-diethylthiophosphate

An outstanding feature of this compound that first came to light in the tests was its very good effect against mosquito larvae. As a result of this finding, we decided to test the active ingredient on a broader scale, and it proved to be most suitable for controlling flies when applied as a residual deposit on walls. In veterinary medicine, the compound has an even wider spectrum of activity than NEGUVON. Today it is chiefly used in veterinary medicine for controlling blow flies and ticks (single-host and multi-host species) as well as biting lice and sheep keds. It also has a good effect against ox warble flies. An especially valuable feature of the compound is that dips prepared with it can be used for several weeks, and furthermore it has a long residual action in the fleece of sheep.

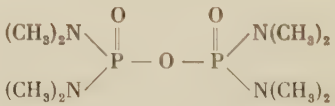
II. Systemic insecticides and acaricides

The organophosphorus compounds opened the way for the systemic treatment of crops, one of the greatest technical advances in the chemical control of plant parasites. Systemic pesticides are taken up by plants, translocated in the system and stored for varying lengths of time. Uptake, translocation and time-dependent storage of active ingredients by the plant are the characteristic features of systemic treatment. Typical features from the aspect of control are the form of effect from the site of application, the so-called translocal effect, the resultant high probability of eradication in that pests are killed which are not directly hit by spray solution, and the time-dependent immunization in the sense that pests susceptible to the active ingredients cannot colonize the treated plants for some time.

It was obviously extremely difficult to find active ingredients which satisfy the many different prerequisites that have to be fulfilled by a systemic insecticide; after uptake, translocation and storage in the plant to have a toxic action on parasites without harming the plant and without rendering the harvest produce in any way unsuitable for consumption.

Following the development of reliable selection and test methods systemic insecticides are today obtained from various groups of chemicals, but the position of the organic phosphoric esters, and especially the "SYSTOX group", has nevertheless remained imperturbable and unopposed. Chemically, this group is characterized by a thiol-, thiono- or thionothiolphosphoric acid being bonded with an alkylmercaptoalkyl substitute. It is the knowledge of this effective configuration that has established the present-day standard of systemic treatment of plants against attacks by aphids and mites.

Before this group was found, it was OMPA which undoubtedly laid claim to being the first really useful insecticide for systemic treatment.



OMPA

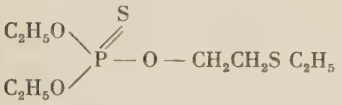
In its original form, OMPA already had the makings of a systemic insecticide: ready resorbability by roots and leaves as the essential property for group

treatment, and a time-dependent immunization of the plant. Spectrum of activity: chiefly effective against aphids and spider mites.

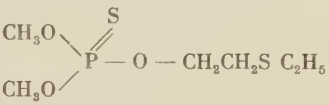
But OMPA had considerable deficiencies of which the very slight initial toxicity should especially be mentioned — it was very slow to act, and it had a very poor direct contact action. That reduced its value for very many purposes, and prompted further intensive research work especially as it was now certain that systemic insecticides could be produced.

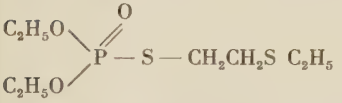
1. SYSTOX® and METASYSTOX®

During the course of further systematic chemical and biological development of the organophosphorus compounds, SYSTOX was discovered. It was a matter of routine for the (corresponding) homologous dimethyl ester to be prepared for new compounds. After all it was an accepted fact as part of the general level of knowledge that as a rule the dimethyl ester is less toxic for mammals and at the same time possesses essentially the same insecticidal activity.

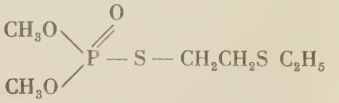


thiono form





thiol form



SYSTOX (DEMETON)

METASYSTOX
(DEMETON-methyl)

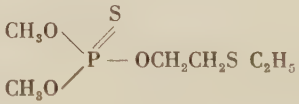
From the aspect of control technique, SYSTOX and METASYSTOX satisfied all the necessary requirements for a systemic insecticide: high initial toxicity (rapidity of action), ready resorbability by leaves and roots, adequate residual action at the right dosage, and a spectrum of activity focused on the control of aphids and Tetranychidae, these being especially acceptable uses for systemic active ingredients. In a manner that was unusually convincing even for good active ingredients, extensive tests confirmed that both products were able to display a considerable increase of efficacy against the controllable species, consequently also improving the economy of the control. That was of enormous advantage to crop protection insofar as spider mites were gaining considerable importance. It was with systemic insecticides that spider mites were reliably controlled for the first time. But aphids, too, gained steadily increasing significance, especially as carriers of the continuously spreading virus diseases. In Europe it was — and in fact still is — chiefly beet yellows which infected more and more areas, and became a serious threat to the cultivation of beets. Shortly after SYSTOX became known, trial controls were carried out with great success. The danger of yellows has now been overcome through the use of METASYSTOX. Very pleasing results were also obtained in the control of leaf roll disease

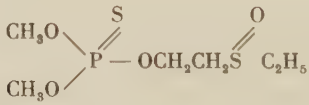
of potatoes. Today one of the highly valued features of crop protection is that persistent viruses can be dependably suppressed in annual crops provided the biological prerequisites (prognosis) are taken into account. But success can also be achieved against non-persistent viruses, with proper organizing.

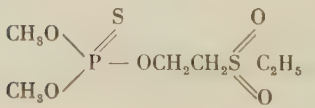
Our comments would not be complete if we were not to mention that biological research, in the development of systemic insecticides, was confronted with completely new tasks which, methodically, involved very great difficulties. A complexity of factors — plant, active ingredient, pest and environment — that were not fully known and differing in their influence, made it incredibly difficult for the efficacy and its conditionality to be accurately determined. Very great efforts had to be made to acquire the active ingredients. The experience, knowledge and findings gained in the process have proved to be very fruitful and stimulative to further research work.

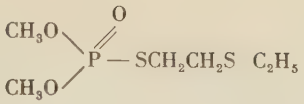
One of our main tasks in establishing the properties of SYSTOX and METASYSTOX was to determine exactly the characteristics of the thiol- and thiono-isomers contained in these compounds. It was soon found that they have different potencies and properties. An important finding was that the thiol-isomer is the carrier of the systemic action. The obvious course was to readjust the product to this isomer; this plan, however, was at first confronted by considerable difficulties of a chemicophysical nature. However, following systematic development work, we succeeded in surmounting these early difficulties. In view of the interesting perspectives opened up by systemic insecticides and considering the possible hazards to consumers of agricultural products, which were always kept under careful observation, the next step was obviously to study in detail the behaviour of these active ingredients in plant and animal organisms. These studies turned out to be very successful.

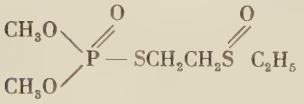
After it had been established that the thiono-compound, which is rich in energy, is transformed in aqueous solutions into the thiol-compound which is poorer in energy, an explanation was found for the observation that toxicity and effect increased when aqueous solutions of the thiono-compound were left to stand. Further studies then revealed that in the plant the isomers of SYSTOX and METASYSTOX undergo oxidation processes at the thioether-sulphur, resulting in the formation of sulphoxides with quadrivalent sulphur and sulphones with sexivalent sulphur. For the insecticidal process, only the oxidation products occur in the plant.

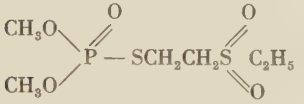






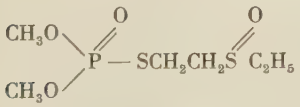




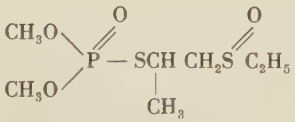


It was further established that such transformations also take place in the mammalian organism. The liver is stated to be the organ for this oxidative metabolism, and in the insect chiefly the intestine, muscle and nerve plexus. Toxicological studies showed that in the SYSTOX and METASYSTOX series the sulphoxides and sulphones have only a fraction of the cholinesterase-inhibitory effect possessed by the corresponding non-oxidized compounds, while on the other hand these differences no longer exist in vivo. It was, therefore, concluded from the results of the tests that in vivo redox reactions are involved, which also enable a change-over from the higher oxidation stages to the lower stages, e. g. from sulphone and sulphoxide to the thiol-compound. Considering that the manner of behaviour is otherwise the same, it may be assumed that similar processes also take place in the insect, although direct evidence of this is still wanting. At all events, a combined effect of several products of metabolism must be reckoned with for SYSTOX and METASYSTOX.

We have studied the toxicological characteristics of the different metabolites in vitro and in vivo, i. e. without and with the plant as the patient and the active component of the phytotherapeutic process. It was found that in vivo the effect of the different transformation products is almost the same, which was only to be expected from what went on in the transformation processes. But there were no significant differences in vitro, either. Nevertheless, when an exact study is made the metabolites can be distinguished from the non-oxidized compounds; they have a slighter effect in the vapour phase. Therefore, the oxidation products have no advantages regarding effect over the non-oxidized starting substances. But they do have the advantage of being a less nuisance with regard to smell. For this reason, we also widely tested the following two active ingredients, and submitted them for official approval:



METASYSTOX R



METASYSTOX S

As expected, they correspond in effect and behaviour to METASYSTOX (i).

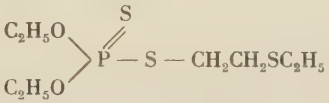
Systemic insecticides can be embodied in plants in the following ways: by spraying the green shoots, by treating trunks and branches, by soil application (watering technique, use of granulates) and by seed treatment. An essential task is to utilize the potencies of the active ingredients as economically as possible by employing the method of application best suited to each particular purpose. The normal method of applying systemic insecticides is to spray the green shoots — dusting is never so effective; trunk and branch treatments as well as 'watering' applications are possible but these are techniques which are restricted to special cases because they involve considerable labour.

Once the practice of treating seed with chemicals for controlling seed-borne and soil-borne fungus diseases and soil pests had been developed into one of the most elegant techniques for applying pesticides, and after it had been found that treatment of seed with systemic insecticides immunizes the shoot against infestation, this method of application was studied from various aspects as a protective measure. Following a number of tests with wet and dry seed dressings, especially on *Vicia faba,* we found in activated carbon an ideal vehicle for systemic active ingredients, a discovery simultaneously made by American research workers. The use of activated carbon made for easy and accurate dosaging of the highly concentrated preparations required for immunizing the relatively voluminous shoot, and also considerably minimized the hazards of plant injuries which, in view of the massive action of large quantities of active ingredient, were always to be expected. Activated carbon formulations constitute slow-flowing sources of active ingredient. We carried out very successful tests with SYSTOX and its metabolites. While attention overseas was concentrated on the control of aphids, spider mites and thrips, especially on cotton, we focused our attention on beets, especially sugar beet. We had very good reason for taking this line of action since it was particularly the beet which was suffering on an increasing scale from early attacks by beet fly and aphids, and furthermore as it had become a matter of much urgency, in view of the lack of labour and following the mechanization of the beet harvest, for an intensive study to be made of the situation regarding peak periods in cultivation work. Ways had to be found for crop protection measures, which were becoming increasingly necessary during the early stage of beet growth, still a peak period of work, to be carried out by methods that would not impose any extra burden on farm management. Prophylactic seed treatment, which affords the young beet plant protection for many weeks against early attack by pests, promised to provide a solution to the problem insofar as it can be carried out at the same time as sowing, which means that no special measures are needed. No additional equipment is required, either.

As well as seed treatment, we also turned our attention to the application of granulates. The principle of this method is that the systemic insecticide is carried by a coarsely granular inert material, and then applied like fertilizers. The active ingredient is taken up by the roots. The application of granular products, however, could only be considered as an advance on spraying from the aspect of farm management, such as accomplished with seed treatment, provided it did not involve any additional work. The course we adopted was to develop granulates of the same size and the same thousand-grain weight as beet seed. After being thoroughly mixed with the seed, the granules are applied in the

drilling operation; the active ingredient is then deposited in the immediate vicinity of the germinating seed, affording the young plants full protection at the right time, just as in the seed treatment technique. The advantage of the granular method over seed treatment is that relatively low percentage products and hence safe formulations can be used, and plant tolerance is better; efficacy and residual action are the same.

Considerations and factors relating to economy and management, especially the problem of labour shortage, determine in this case the course to be taken regarding the techniques that are to be employed for applying pesticides, added to which is the necessity of attaining new effects. Even though SYSTOX and METASYSTOX can be applied by the described methods, we nevertheless wanted active ingredients with a broader spectrum of activity and a longer residual action. We found these in the thionothiolphosphoric esters of the Syston configuration, to be more precise in DISYSTON.



DISYSTON

The homologous dimethyl ester is considerably weaker when applied by the methods under discussion. DISYSTON is readily resorbed by the roots, and affords the plants longer protection than the thiol-compound, this being due to its greater stability to hydrolysis. The spectrum of activity is also broader. Resorption by foliage and thus the residual action of the product when sprayed are not so good as for the corresponding thiol-compounds, due to the poor solubility in water. When used as a seed dressing or in granular formulation, the residual action on beets usually lasts for about 7 to 8 weeks in the climatic conditions of Central Europe.

It should be emphasized here that the residual action is not an absolute but a relative factor. At one and the same dosage, it is dependent upon the plant species, the weather, the rate of plant growth, and the species-, stage- and strain-specific behaviour of the pests.

The action of DISYSTON in plant and animal organisms is exactly known today. Like SYSTOX, DISYSTON is also transformed into different oxidation products. As well as the sulphoxide and sulphone of the thionothiol-compound, the corresponding oxidation products of thiol-Systox are formed. All four metabolites combine to mold the systemic process.

We have tested thousands of organophosphorus compounds for their systemic action, and of these several hundred compounds have been tested for their suitability as systemic seed dressings. We have not yet come across an active ingredient which could be compared with DISYSTON for seed treatment and granular application. But as current tests show, research in this direction is by no means completed, and one can hope to achieve further progress. This applies not only to systemic insecticides but also to ectotherapeutic active ingredients. It is merely in cases where resistance to organophosphorus compounds has

developed that one will have cause to search for new active ingredients. In crop protection, this has so far only been necessary for control of spider mites. We have made full allowance for this fact, and have developed new active ingredients.

Manuscript submitted on 19. 8. 1961

Large-scale field trial with METASYSTOX® in seed potato production area of Middle Franconia

by Günter Schramm, Ansbach

The seed potato production industry in Bavaria is today having to fight for its existence; success can only be ensured provided all possible means of effectively improving and remedying the situation are carefully considered to form an aimed plan of approach. In its decisive phases, seed potato production has today become a battle against the various virus diseases.

Elimination of virus diseases of plants is basically possible by direct protection and indirect control (3). For the practical seed production technique, only methods of indirect control have been developed at present. Besides the breeding of resistant varieties, these methods cover the wide sphere of infection prevention in which possibilities lie with the seed producer — control of vectors on potato plants and on winter hosts. The control of vectors had not been widely practised by seed potato growers in the past, not for want of need but because, in view of the high costs of the pesticides, the success of control programmes had not been adequately proved for the different virus species — except leaf roll.

As part of a large production and test programme extending over many years, organized by the Seed Potato Producers' Association of Middle Franconia (5), a large-scale trial control of aphids with METASYSTOX was, therefore, carried out in 1960, which was generously supported by the Bavarian State Ministry of Food, Agriculture and Forestry.

I. Preliminary tests, 1959

In 1959, two preliminary tests were conducted with the leaf-roll susceptible varieties Oberarnbacher Frühe and Agnes, grown for seed production; there were no replications. Two plots were chosen which were situated close to virus-infected stands. The two applications of METASYSTOX were carried out exactly 8 and 20 days, respectively, after emergence. Full protection was given for up to about 30 days after emergence, and persisted until after the removal of secondary-infected plants. Afterwards the usual treatment was continued by the seed growers. The tuber tests gave the following result:

® = Registered trade mark of Farbenfabriken Bayer AG, Leverkusen

Table 1:

1959		Leaf roll	Streak	Crinkle	Mild mosaic	Latent
Unterwurmbach Agnes, 0·5 hectare certified progeny	u)	72 %	0 %	0 %	2 %	10 %
	s)	11 %	0 %	0 %	1 %	0 %
Wassermungenau Oberarnbacher Frühe, 1 hectare	u)	7 %	0 %	0 %	0 %	4 %
Vorvermehrung*	s)	1 %	2 %	2 %	6 %	2 %

u) = untreated, s) = sprayed
* a grade between high quality and progeny.

The test year 1959 was a year of severe infection in the region under discussion. The healthiest post-war growth coincided with an enormous occurrence of aphids extremely early in the season. According to the findings of the Warning Service, the top killing times were about July 27, and could only be observed in very few cases for economic reasons. The test rejection quotas for Middle Franconia provide a measure of the extent of the infection (leaf roll tests):

1960	2·8 %	of the registered acreage
1959	**14·0 %**	„ „ „ „
1958	0·5 %	„ „ „ „
1957	9·7 %	„ „ „ „
1956	1·6 %	„ „ „ „

It is only by taking these quotas into account that the infection rate will also be comprehensible in the case of Agnes — Unterwurmbach. With regard to tendency, the result for leaf roll met with expectations (4); in the absolute effect, it was surprisingly good and significant.

The results for the other virus species are not clear, especially for Y which is much more important than leaf roll. It was especially this fact that prompted the decision to go ahead with the testing of METASYSTOX for vector control. It is stated by other authors that the use of METASYSTOX against early virus Y infections is promising only when large-scale applications are carried out, but at the same time it is mentioned that these have not yet been tried out (2, 4).

II. Object of tests, 1960

The object of the tests can be very briefly outlined. On the one hand, it was required to confirm the good effect of a proper application of METASYSTOX against leaf roll; on the other hand, and what was more important, the unknown and indefinite influence on the other virus species, especially on veinal necrosis, had to be investigated. In this respect, the purpose of the undertaking was to furnish only practical results, and not scientific data.

The economic aspect, i. e. the question whether such a programme can be financially borne by the seed producer, was not considered in detail, although a 3rd. spray application was purposely left out of the schedule from the outset because this spray really seems to be a financial burden at least for the majority of growers breeding first-quality stock seed and progeny plants (state in 1960). The programme was required to guarantee continuous protection until after removal of the secondary-infected plants. The large-scale treatment was planned to include all potatoes in the test area — also those of growers outside the community — irrespective of the purpose for which the potatoes were to be used later. The spray applications were planned to supplement and not to replace seasonable and continual selection work.

III. Test procedure

For the large-scale test, the community of Wassermungenau in the rural district of Schwabach was chosen, where the potato acreage is made up of 79·6 hectares of seed potato fields and 14·7 hectares of consumer potatoes. A good and old-established stock of seed producers is confronted in Wassermungenau by a heavily split-up and seemingly unsound production of consumer potatoes, practised by part-time and very small growers. This consumer potato production can only be eliminated with extreme difficulty, and then not fully.

At a meeting of the community, it was resolved to go ahead with the project, and a plan of work was agreed on. Three spraying machines were made available by the local seed potato producers' association, Wassermungenau.

In order to coordinate timing of the first spray, growers were urged to stimulate sprouting of late and slow-germinating varieties, and to plant them out before the others. May plantings were largely avoided, and the planting time was kept as short as possible.

The date of the first spray was fixed according to the time of emergence and top growth; it was between May 27 and 31, seven to ten days at the most after emergence. It is vitally important that the emerged plants are treated with the systemic product while they are still completely free of aphids. A small group of late emerging plants was treated in early June. Records of emergence and early growth were kept by a seed-potato growing expert who also prepared the spraying schedule and supervised the work. The schedule chosen for the first operation was also used in the second treatment.

The second treatment was carried out between June 8 and 14, nineteen to twenty-four days at the most after emergence, without allowing for the late emergence of the small group in the first operation. In fact it was planned to complete the second treatment in a shorter time but this was not possible due to breakdowns on two spraying machines. The dosage used in the first application was 1·2 litres of METASYSTOX (i)* per hectare, and in the second treatment 1 litre. A row treatment was not carried out.

IV. Results for leaf roll virus

The evaluation was based in all cases on the results of the tuber test, which is carried out as part of the routine procedure for official approval of seed. These results were obtained in the Igel-Lange stain test, combined with a subsequent control of positive tubers by the tuber index method. The results for

* 25 % a. i.

the upper grades and first-quality stock seed included in the evaluations are those obtained solely by the tuber index method. The tubers were sampled by members of the official seed approval agency.

The results for the METASYSTOX-treated area are compared in all cases with the so-called 'model communities', adjoining districts which have attained a very high level of concentration and seed production technique. This is ensured by the employment of technicians permanently stationed in the 'model communities'; one technician looks after 100 hectares of seed potatoes. Other measures include the supply of new seed each year to few growers who cultivate consumer potatoes, and also screening-off of the 'model communities' from adjoining areas (1, 5). There is no doubt that the density of seed potato cultivation and the intensity of seed production work in the 'model communities' still considerably surpass that in the METASYSTOX area.

Considering the described prerequisites and in view of the chosen comparison region, it can be safely stated, without overestimating the absolute figures, that on the average leaf roll infection was reduced by half.

Table 2: Average leaf roll infection of all grades, tuber test 1960

	METASYSTOX area			Model communities (5)		
Seed potatoes in hectares % of total potato acreage	79·6 ha. 76 %			204·4 ha. 92 %		
Variety grouping according to leaf roll susceptibility	% leaf roll		rel.	% leaf roll		rel.
high (Sieglinde)	6·8	(6)	27	25·5	(9)	100
medium-high (Agnes, Lerche, Lori, Maritta, Ob. Frühe)	2·7	(20)	33	8·1	(36)	100
medium (Anko, Datura, Irmgard, Magna, Panther)	1·5	(30)	80	1·9	(144)	100
medium-low (Benedetta, Delos, Saskia)	1·1	(16)	39	2·8	(91)	100
low (Eva, Pavo)	0·08	(26)	29	0·28	(58)	100
split varieties	2·0	(7)	35	5·8	(15)	100
Average	1·66	(105)	52	3·22	(353)	100

N. B.: Variety grouping according to "Sortenratgeber Kartoffeln", DLG Verlag, Frankfurt, 1960, 2nd. ed. No. of samples in brackets.

A notable feature was that the effect, in my opinion, proved to be greater on varieties of high leaf roll susceptibility than on those of medium and low susceptibility. As far as leaf roll only is concerned, the ability of the latter susceptibility groups to be certified as upper grades was not in doubt, even without a METASYSTOX treatment, nor was their ability to be selected for further cultivation for seed production. The leaf roll infection rates of 0·28 to 2·8 % in these variety groups prove it. In the test year, METASYSTOX brought about a further reduction down to 0·08 to 1·5 %, which, however, was of little interest for the individual seed producer in the case in question.

The situation is different among the varieties of medium to high susceptibility. The average infection rate in this group clearly shows that the limit of 6 % for first-quality stock seed could no longer be maintained without METASYSTOX in 1960. At a rate of 8·1 % leaf roll infection, selection of the following crop for progeny approval can hardly be considered economical, either. From the consumer standpoint, a good progeny quality was produced but the seed potato growers had to restock. In the METASYSTOX area, approval of first-quality stock seed and suitability for continued seed production remained secure for this susceptibility group.

In the high susceptibility group, represented only by the variety Sieglinde, the same was attained in the METASYSTOX area as with the medium to highly susceptible varieties in the "model region", in other words progeny quality without suitability for continued cultivation in seed potato production. In this respect, it should be explained that in 1960 the same Sieglinde origin — which with an 8 to 10 % secondary leaf roll infection rate was not particularly suitable — was newly planted in both regions. None of the batches that had not been treated with METASYSTOX was approved as progeny.

Table 3: No. of stands of all grades according to leaf roll infection rate, tuber test 1960

Variety grouping according to leaf roll susceptibility	METASYSTOX area				Model communities (5)			
No. of stands	105				353			
% leaf roll	0	1—6	7—12	over 12	0	1—6	7—12	over 12
high	—	2	4	—	—	—	—	9
medium-high	8	11	—	1	6	13	9	8
medium	19	11	—	—	68	65	9	2
medium-low	10	6	—	—	27	54	10	—
low	25	1	—	—	54	3	1	—
split varieties	4	3	—	—	4	7	3	1
Total	66	34	4	1	159	142	32	20
Free	63 %				45 %			
First-quality limit		95 %				85 %		
Progeny limit			99 %				94 %	

The excellent results obtained with the varieties of medium-high to high susceptibility were undoubtedly due to the large-scale spraying programme.

The same numerical values, expressed according to leaf-roll infected groups, show that 63 % of all METASYSTOX-treated batches were found to be free of leaf roll virus in the tuber test, while the figure for untreated was only 45 %. A more significant fact is when leaf roll disease is evaluated alone, 95 % of all treated stands would have been suitable for approval as first-quality stock seed, while for untreated stands only 85 % would have been approved. The maximum progeny limit was reached by 99 % of the examined samples, in the one case, and by 94 % in the other. That means 6 % losses without treatment, and merely 1 % with vector control.

The upper grades alone showed the following values for leaf roll; for greater comparison, the remaining area of Middle Franconia with all outlying farms is included:

Table 4: Average leaf roll infection of upper grades in %, tuber test 1960

Variety grouping according to leaf roll susceptibility	METASYSTOX area			Model communities		Rest of Middle Franconia	
high and medium-high	%	2·5	(6)	4·6	(5)	9·3	(11)
	rel.	56		100		205	
medium	%	0·2	(6)	1·1	(61)	1·4	(34)
	rel.	15		100		129	
medium-low	%	0·7	(3)	1·2	(9)	1·3	(12)
	rel.	57		100		103	
split varieties	%	0·0	(4)	0·6	(12)	0·8	(29)
	rel.	—		100		140	
Total	%	1·0	(19)	1·35	(87)	2·41	(86)
	rel.	74		100		179	

The results agree to a certain extent with those discussed above. On the whole, the leaf roll infection rate could only be reduced by a quarter for the upper grades. The reason is most probably that producers of upper grades naturally attempt to achieve higher production by incurring still greater expenditure on breeding; on the other hand, treatment with METASYSTOX, especially on varieties susceptible to leaf roll, will bring about an additional improvement that is not possible by other means, no matter how much outlay is incurred on seed production.

The values for the rest of Middle Franconia further demonstrate the performance of the so-called model communities.

V. Results for other virus species

The studies and evaluations for the other viruses were limited to 192 first-quality and upper grades because time and costs did not allow us to deal with the mass of progeny batches. The smallest number of samples (number of replications) taken for calculating the averages, was 19 in the overall result and 9 in the variety grouping.

Virus X, which is transmitted only by mechanical means, was established but its slight incidence permitted no conclusions to be drawn. Stem mottle virus has so far not occurred at all in Middle Franconia. The remainder of this section will, therefore, be devoted to the old potato virus Y, virus A and virus Y. It was not possible to separate A and Y because the only results available were for seed pieces.

Table 5: Average disease percentages for upper grades, tuber test 1960

Region		Leaf roll	Old potato virus Y	Crinkle A + Y	Mild mosaic A + Y	No. of samples
Model communities (5)	%	1·35	0·02	1·04	2·00	87
	rel.	100	100	100	100	
METASYSTOX area	%	1·00	0·05	1·46	9·32	19
	rel.	74	250	140	466	
Rest of Middle Franconia	%	2·41	0·06	1·51	4·46	86
	rel.	179	300	145	223	

In contrast to persistent leaf roll virus, the reaction of the other viruses is just the opposite, namely a multiplication. The absolute percentages for the old potato virus Y do not permit any conclusions to be drawn, but the other figures do. Furthermore, only manifest diseases are given here, and a still greater worsening of the situation due to latent virus must also be taken into account.

With respect to mild mosaic forms, the situation in the METASYSTOX area is worse than in the rest of Middle Franconia. The region of model communities, with the most intensive and best aimed seed production technique, is superior; this is even more evident in the grouping of variety susceptibility to veinal necrosis.

Varieties with medium and over medium susceptibility to virus Y show markedly high average infection of crinkle, severe and mild mosaic in the METASYSTOX area. Among the varieties of below medium susceptibility, the variety Eva, as a carrier of virus A, dominates the overall picture. When the variety Eva is omitted, the regional comparison, parallel to the Y-susceptible varieties, also shows significant differences. Influence by METASYSTOX

Table 6: Average disease percentages for upper grades, tuber test 1960

Veinal-necrosis susceptibility group	Old potato virus Y				Crinkle		Mild mosaic	
	Model communities		METASYS-TOX area		Model communities	METASYS-TOX area	Model communities	METASYS-TOX area
over medium and medium*	0·01	(66)	0·11	(9)	0·52	2·11	1·04	10·22
below medium**	0·05	(21)	0·00	(10)	1·21	1·00	5·70	8·50
Average	0·02	(87)	0·05	(19)	1·04	1·46	2·00	9·32

*) over medium and medium: varieties Agnes, Anko, Benedetta, Irmgard, Ob. Frühe, Panther

**) below medium: varieties Datura, Eva, Lerche, Lori, Pavo, Saskia

is then no longer evident on the remaining varieties that are less susceptible to Y.

As regards virus Y, the material was unfortunately insufficient for the various questions concerning multiplication quota, variety-susceptibility and latency to be fully settled. It can only be established that in the case in question, METASYSTOX led to a multiplication of the nonpersistent viruses. From this, it may be concluded that METASYSTOX can be successfully used for suppressing leaf roll, without any great risks on the other side, provided:

1. there is a complete absence of varieties with over medium susceptibility to virus Y;
2. varieties of medium susceptibility are in limited abundance;
3. a maximum level of seed production density (i. e. percentage of seed potato production in relation to total potato cultivation) and seed production intensity is attained.

VI. Summary of results

Two timely METASYSTOX treatments of seed potatoes, carried out in a large-scale field trial to keep the stands free of aphid infestation until removal of the secondary-infected plants, produced the following results:

a) Leaf roll was reduced by almost 50 %, calculated as an average for all grades and in comparison with areas that have a higher density of seed potato production and greater seed production intensity.

b) By using METASYSTOX, varieties of medium to high susceptibility to leaf roll were raised to a quality at which they were suitable not only for approval but also for further seed production. Without METASYSTOX, only approval as progeny was ensured.

c) The treatment of varieties showing high leaf roll susceptibility with METASYSTOX enabled them to be approved as progeny, which was not possible in 1960 in the comparison area without METASYSTOX.

d) Nonpersistent viruses showed an increase following METASYSTOX application, which cannot be tolerated at least for varieties of over medium susceptibility to virus Y. The question of an increase of latent virus remains unanswered.

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The use of GUSATHION® in fruiticulture in South Africa

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Introduction

GUSATHION-(0,0-dimethyl-S-[benzaziminomethyl]-dithiophosphate), is a phosphoric ester developed by Farbenfabriken Bayer AG, Leverkusen. It was first introduced in South Africa in 1958 as a 25 % wettable powder formulation for the control of certain citrus pests. The following year the same formulation was introduced for the control of insect pests of deciduous fruit. It has subsequently become a well-established pesticide in these two cultures, having proved itself in practice. The purpose of this paper is to outline the experimental work which was carried out with the product and its current fields of use in South Africa.

I. Citrus

Efficacy of GUSATHION against scale insects

Since the introduction of Parathion in South Africa shortly after world war II, this insecticide has almost completely replaced the former widely used method of HCN-fumigation under tents for the control of scale insects. The

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Table 1: Efficacy of different concentrations of GUSATHION against *Coccus hesperidum* L.

Date: 31. 12. 1957
Test Plants: 5—6 years old Citrus trees (Valencia variety)
Method of Application: Power sprayer 400 lbs. per square inch
Rate of Application: 2·5 to 5 gallons per tree

Preparation	Concentration active ingredient	Percentage mortality after: 4 days	10 days	24 days	50 days
GUSATHION 20 % Emulsifiable concentrate	0·04 %	100	—	100	100
GUSATHION 20 % Emulsifiable concentrate	0·03 %	94	—	99	100
GUSATHION 20 % Emulsifiable concentrate	0·025 %	91	—	98	99
GUSATHION 20 % Emulsifiable concentrate	0·02 %	75	—	94	98
GUSATHION 25 % w. p.	0·025 %	—	100	—	—
GUSATHION 25 % w. p.	0·015 %	—	96	—	—
GUSATHION 25 % w. p. + FOLIDOL 25 % w. p.	0·025 % + 0·05 %	—	100	—	—
Control		0	3	12	51

most important scale insect and the one which is prominent in all citrus areas of South Africa is Red Scale *(Aonidiella aurantii* Mask.). Other scale insects which can also cause trouble if not controlled are Mussel Scale *(Lepidosaphes pinniformis)* [Bché] Kirk., Circular Purple Scale *(Chrysomphalus ficus* Ashm.) and Soft Brown Scale *(Coccus hesperidum* L.). These three species can, however, be regarded as relatively of minor importance compared with Red Scale which is in fact the most destructive species and the one most difficult to control. Mussel Scale and Circular Purple Scale can be effectively controlled

with comparatively low dosages of Parathion, whilst for the control of *Aonidiella aurantii* a high concentration of 0·075 % a. i. in high volume sprays is required. In order to obtain satisfactory control, about 10—15 gallons of spray are applied on a full-grown tree using a minimum spray pressure of 400 lbs. per square inch.

In recent years Soft Brown Scale has gained prominence and in fact in several citrus areas it has temporarily become even more important than Red Scale. The reason for this increased importance can be mainly attributed to the fact that Parathion even at a concentration of 0·075 % a.i. as applied for other scale insects has virtually no effect on Soft Brown Scale. Furthermore, the natural enemies of this species, which previous to the introduction of Parathion kept it under control were eliminated by the regular use of Parathion against other scale insects. The result has been that in recent years this pest has been left uncontrolled and has been able to establish itself and become a real problem in certain areas. In view of the importance which was attached to Soft Brown Scale at the time, preliminary small-scale tests with a number of insecticides were carried out in 1956—1957. In these tests GUSATHION 20 % emulsifiable concentrate showed considerable promise to control this scale insect.

Subsequently extensive tests were carried out with this preparation, as well as with wettable powder formulations in the citrus growing regions of the Transvaal. The reason for including GUSATHION wettable powder formulations in these tests is that under South African conditions, such formulations are known to be less phytotoxic to citrus fruit than emulsifiable concentrates. It is for this reason also that Parathion wettable powder formulations are almost exclusively used for the control of citrus pests, and little use is made of the emulsifiable concentrates.

The results of these field tests confirmed those obtained in the preliminary trials. Mortality figures as presented in Table 1 may be regarded as representative of the results obtained with GUSATHION.

It should be mentioned that the spraying pressure at which GUSATHION sprays are applied has a marked influence on its efficacy against Soft Brown Scale. Results have shown that in order to obtain satisfactory control when using knapsack sprayers, a concentration of 0·08 % a. i. is necessary. This concentration can, however, be reduced to 0·04 % when using spraying machines operating at a minimum pressure of 400 lbs. per square inch.

Effect of GUSATHION on other citrus pests

1. Red Scale *(Aonidiella aurantii* Mask.)

As mentioned earlier this scale insect is the most important pest of citrus in South Africa. For its control, Parathion w.p.* at a concentration of 0·075 % a.i. is customarily used.

Although different concentrations of GUSATHION were tested for the control of this scale insect, it was finally established that as is the case with Parathion, a relatively high concentration of 0·075 % a.i. is necessary to provide satisfactory control (see Table 2). At this high concentration, however, GUSA-

* w. p. = wettable powder

Table 2: Efficacy of equivalent concentrations of GUSATHION and Parathion for control of *Aonidiella aurantii* (Mask.)

Date: 11. 8. 1957
Test Plants: 5 year old Valencia citrus trees
Method of Application: At 3/4 petal-drop with power sprayer 600 lbs. per square inch
Rate of Application: 5 gallons per tre

Preparation	Concentration a. i.	Percentage fruit infested by Red Scale after 77 days	after 151 days
GUSATHION 50 % w. p.	0·075 %	3	9
Parathion 25 % w. p.	0·075 %	9	15

Table 3 (a): Efficacy of different combinations of Parathion and GUSATHION for the control of *Aonidiella aurantii* (Mask.)

Date: 8. 10. 1957
Test Plants: 5 year old Valencia citrus trees
Method of Application: At 3/4 petal-drop using a power sprayer 300 lbs. per square inch
Rate of Application: 5 gallons per tree

Preparation	Concentration active ingredient	49 days after application Percentage Red Scale killed on branches	Percentage fruit infested
Parathion 25 % w. p.	0·075 %	86	26
GUSATHION 50 % w. p.	0·04 %	78	63
GUSATHION 50 % w. p. + Parathion 25 % w. p.	0·02 % + 0·04 %	90	16
GUSATHION 50 % w. p. + Parathion 25 % w. p.	0·02 % + 0·05 %	99	1
GUSATHION 50 % w. p. + Parathion 25 % w. p.	0·03 % + 0·04 %	99	0·5
Control		24	100

THION would not be an economical proposition and farmers would prefer to use Parathion instead. A combination of GUSATHION and Parathion appeared to be more promising and field tests were consequently carried out using different combinations of the two products. Some results of these tests are tabulated in Tables 3 (a) and (b) and indicated a combination of 0·05 % a.i. Parathion and 0·025 % a. i. GUSATHION to be as effective as Parathion at 0·075 % a. i. for the control of Red Scale and would in addition also control Soft Brown Scale. At present such a combination (ready for use) is marketed in South Africa in addition to GUSATHION 25 % w. p. and FOLIDOL (Parathion) 25 % w. p., and has proved very suitable for control of both Red Scale and Soft Brown Scale on numerous citrus farms.

Table 3 (b): Efficacy of different combinations of Parathion and GUSATHION for the control of *Aonidiella aurantii* (Mask.)

Date: 27. 9. 1958
Test Plants: 6 year old Valencia citrus trees
Method of Application: Power sprayer 400 lbs. per square inch
Rate of Application: 4 gallons per tree

Preparation	Concentration active ingredient	Infestation before treatment % twigs infested	% fruit infested 51 days after treatment
FOLIDOL 25 % w. p.	0·075	31	20
GUSATHION 25 % w. p.	0·075	52	23
GUSATHION 25 % w. p. +	0·025	46	16
Parathion 25 % w. p.	0·05		

2. Aphids (*Aphis citricidus* Kerk)

Aphids may be regarded as one of the minor pests of citrus although they do occasionally become troublesome. Tests have shown that GUSATHION at a concentration of 0·025 % a.i. will provide very good control of this pest.

3. Citrus Red Mite (*Metatetranychus citri* Mc.Gr.)

Citrus Red Mite can cause severe damage in certain of the citrus growing regions of South Africa, necessitating the use of specific miticides for its control. In other citrus regions the appearance of the pest is more sporadic and infes-

tations will often disappear on their own accord without any control measures being taken. Tests with GUSATHION at a concentration of 0·025 % a.i. have shown that it possesses a good initial effect against the pest, but that its lasting properties are significantly inferior to those of recognized miticides such as 1,1-bis-(4-chlorphenyl)-2,2,2-trichloroethanol and 2,4,4,5-tetrachlorodiphenylsulfone. Its effect is therefore comparable to that of Parathion and it is used only to a limited extent in citrus regions where Red Mite occurs sporadically.

4. Thrips (*Scirtothrips aurantii* Faure)

For control of Thrips, Parathion at a concentration of 0·075 % a. i. is usually applied at 3/4 petal-drop. Tests with GUSATHION applied in the same manner and at equivalent concentration have shown that it will also provide effective control of this pest. Further experimental work is still necessary to determine whether lower concentrations would also be effective.

5. Other Scale Insects

Mussel Scale (*Lepidosaphes pinniformis* [Bché] Kirk.) and Circular Purple Scale (*Chrysomphalus ficus* Ashm.) are both effectively controlled by using a combination of Parathion and GUSATHION recommended for Red Scale and Soft Brown Scale control.

II. Deciduous fruit

Efficacy of GUSATHION against codling moth

In the deciduous fruit growing regions of the Western Cape Province, Codling Moth (*Cydia pomonella* L.) has ever since the beginning of commercial fruit growing been the most important pest. Prior to the discovery of dichlorodiphenyltrichlorethane in the early forties, arsenical insecticides were used for the control of Codling Moth. Apart from the fact that a considerable number of applications were necessary before effective control was obtained, arsenical sprays under South African conditions often exhibited marked phytotoxicity and had a severe adverse effect on the trees. Also due to the large number of applications which had to be carried out, undesirable arsenic residues accumulated on the fruit, and had frequently to be removed by washing with diluted hydrochloric acid solution.

For these reasons, the introduction of dichlorodiphenyltrichlorethane in 1945—1946, with its many advantages, was a great improvement. Although the use of dichlorodiphenyltrichlorethane in the Cape Western Province as well as in certain European countries, had the disadvantage of greatly increasing infestations of Red Spider and Woolly Apple Aphis on fruit trees, it has been used successfully for Codling Moth control for many years. However in 1958 some growers complained that in spite of adhering to the recommended spray programme which had provided effective control in the past, they did not obtain satisfactory control of Codling Moth. Such complaints became more frequent during the following season and even complete failure of dichlorodiphenyltrichlorethane to control this pest was reported. The belief that Codling Moth was becoming resistant to dichlorodiphenyltrichlorethane gained ground, and a search for another insecticide to meet the threat to the fruit-growing industry became a matter of urgency.

Table 4: Results of field trials conducted with GUSATHION 25 % w. p. against *Cydia pomonella* L. in the Stellenbosch area 1958—1959

Test Plants: 7 year old Golden Delicious apple trees
Layout of Test: Randomized single tree plots, replicated 10 times for each treatment
Method of Application: Power driven sprayer
Number of Applications: Five: viz. 21. 11. 1958, 5. 12. 1958, 20. 12. 1958, 9. 1. 1959, 8. 2. 1959

Preparation	Concentration	Total number of apples harvested	Number infested with codling moth	Percentage infestations of total number of apples
GUSATHION 25 % w. p.	1 lb./100 gals. (0·025 % a. i.)	1078	80	7
GUSATHION 25 % w. p.	2 lbs./100 gals. (0·05 % a. i.)	979	30	3
Dichlorodiphenyl-trichlorethane 50 % w. p.	2 lbs./100 gals. (0·1 % a. i.)	987	165	17
Control		1039	461	44

Table 5: Results of field trials conducted with GUSATHION 25 % w. p. against *Cydia pomonella* L. in the Elgin area (1958—1959)

Test Plants: Ohenimuri apple trees
Layout of Test: Randomized single tree plots replicated 12 times for each treatment
Method of Application: Power driven sprayer
Number of Applications: Five viz: 10. 11. 1958, 24. 11. 1958, 8. 12. 1958, 22. 12. 1958, 13. 1. 1959

Preparation	Concentration	Total number of apples	Number infested apples	Percentage infestation
GUSATHION 25% w. p.	1 lb./100 gals. (0·025% a. i.)	8595	44	0·51
GUSATHION 25% w. p.	2 lbs./100 gals. (0·05% a. i.)	8197	6	0·07
Dichlorodiphenyl-trichlorethane 50% w. p.	2 lbs./100 gals. (0·1% a. i.)	9104	270	2·97
Control		7862	1825	23·21

Table 6: Results of field trials conducted with GUSATHION 25 % w. p. against *Cydia pomonella* L. in the Stellenbosch area (1959—1960)

Test Plants: 8 year old White Winter Pearmain apple trees

Layout of Test: Randomized single tree plots replicated 8 times for each treatment

Method of Application: Power driven sprayer

Number of Applications: Six, viz: 9. 11. 1959, 26. 11. 1959, 11. 12. 1959, 29. 12. 1959, 19. 1. 1960 and 15. 2. 1960

Preparation	Concentration	Total number of apples harvested	Total number of infested fruit	Percentage infestation
Methyl GUSATHION 25 % w. p.	1/2 lb./100 gals. (0·0125 % a. i.)	1793	30	1·67
	1 lb./100 gals. (0·025 % a. i.)	1469	1	0·07
Ethyl GUSATHION 25 % w. p.	1/2 lb./100 gals. (0·0125 % a. i.)	1147	44	3·84
	1 lb./100 gals. (0·025 % a. i.)	1167	5	0·43
Dichlorodiphenyl-trichlorethane 50 % w. p.	2 lbs./100 gals. (0·1 % a. i.)	1173	242	20·63
Control		941	548	58·24

Two field tests with GUSATHION 25 % wettable powder were therefore conducted in the Elgin and Stellenbosch areas of the Western Province during the 1958/59 season. The results of these two tests are given in Tables 4 and 5, and showed that GUSATHION at a concentration of 0·025 % a.i. was highly effective for the control of *Cydia pomonella* L.

As a result of these tests, GUSATHION was introduced for control of Codling Moth, and during the 1959/60 season it was used commercially on a large scale in various districts of the Western Province. At the same time, further field tests were carried out with the product as well as with the Ethyl derivative at the standard concentration of 1 lb. per 100 imperial gallons water and at a lower concentration of 1/2 lb. per 100 gallons water. These tests were again conducted in the Elgin and Stellenbosch regions on the same test sites used in the previous season. The results obtained are tabulated in Table 6 and 7, and proved that even at a concentration of 1/2 lb. per 100 gallons water (0·0125 % a.i.), satisfactory control of Codling Moth could be achieved. Following these results it was possible to reduce the recommended concentration to 3/4 lb. per 100 gallons of water for the 1960/61 season. At present 5 applications of GUSATHION wettable powder at an interval of 14—21 days, commencing at the 3/4 petal-drop stage, are recommended and used with great success.

Table 7: Results of field trials conducted with GUSATHION 25 % w. p. against *Cydia pomonella* L. in the Elgin area (1959—1960)

Test Plants: Ohenimuri apple trees
Layout of Test: Randomized single tree plots replicated 7 times for each treatment
Method of Application: Power driven sprayer. Operating pressure 300 lbs./sq. inch
Number of Applications: Six applications at intervals of 2—3 weeks

Preparation	Concentration	Total no. fruit	Percentage infestation
Methyl GUSATHION 25 % w.p.	0·025 %	7406	0·5
Methyl GUSATHION 25 % w.p.	0·0125 %	8419	0·8
Ethyl GUSATHION 25 % w.p.	0·0125 %	9104	1·7
Ethyl GUSATHION 25 % w.p.	0·025 %	8584	1·0
Dichlorodiphenyltrichlorethane 50 % w.p.	0·1 %	7979	4·0
Control		9936	15·5

Effect of GUSATHION against other pests in deciduous fruit

For the compilation of an effective and at the same time economical deciduous fruit spray programme, which involves all major pests, it is essential to know the strong points as well as limitations of a new insecticide. With this view, tests with GUSATHION against Red Spider (*Tetranychus bimaculatus* Harvey), Bryobia Mite (*Bryobia praetiosa* Koch) and Woolly Apple Aphis (*Eriosoma lanigerum* Hausm.) were conducted during the 1958/60 period.

1. Red Spider (*Tetranychus bimaculatus* Harvey)

In the case of Red Spider, difficulties were experienced in obtaining conclusive results due to the fact that this species had developed a resistance to phosphoric insecticides in certain areas. Resistance was first observed in the Elgin area in 1957 and subsequently developed to such a level that control with the conventional phosphoric insecticides was completely unsatisfactory. In the Elgin district resistance was acquired after approximately 35 spray applications with different phosphoric insecticides stretching over several years. Experi-

mental work carried out in North Italy where European Red Mite *(Paratetranychus pilosus)* had also developed resistance to phosphoric insecticides has indicated that although GUSATHION is also a phosphoric insecticide, it will provide very good control of the resistant strain of the mite.

The GUSATHION formulation used in North Italy for Red Mite control is, however, an emulsifiable concentrate. Emulsifiable concentrates of GUSATHION have been proved to be more effective for Red Mite control than wettable powder formulations, but under South African conditions the former formulation was found to be phytotoxic to the fruit and had to be discarded in favour of wettable powder formulations.

Tests conducted with GUSATHION 25 % w. p. at a concentration of 0·025 % a. i. on the Red Spider strain resistant to phosphoric insecticides, indicated that the product only provides partial control of the pest, and that its efficacy was significantly inferior to that of other specific miticides. Furthermore, due to the fact that resistance to phosphoric insecticides was becoming widespread in the Western Province, the product could not even be recommended for the control of the normal strain of Red Spider, although it was found to be effective. It was, however determined that when GUSATHION is applied at regular intervals for the control of Codling Moth, the normal strain of Red Spider is at the same time kept under control. In the areas where Red Spider is resistant to phosphoric insecticides, the pest is also kept in check during the period covered by a GUSATHION programme, but will increase rapidly soon after the final GUSATHION spray has been applied, and require special treatment with a non-phosphoric miticide.

2. Bryobia Mite *(Bryobia praetiosa* Koch)

Under South African conditions Bryobia Mite infestations reach their peak during November to December. The pest is effectively controlled with METASYSTOX at a concentration of 0·1 % preparation, applied when the greater percentage of winter eggs have hatched. Tests carried out with GUSATHION for the control of *Bryobia* therefore also included METASYSTOX for comparison. It was found (see Table 8) that 2 applications of GUSATHION at a concentration of 1 lb. per 100 gallons water (0·025 % a. i.) controlled *Bryobia* as well as one application of METASYSTOX. It was subsequently also established that GUSATHION sprays, as recommended for Codling Moth control, also keep Bryobia Mite under control. It is therefore unnecessary to apply special treatments for the control of Bryobia Mite during the period covered by a GUSATHION spray programme.

3. Woolly Apple Aphis *(Eriosoma lanigerum* Hausm.)

Previous to the introduction of dichlorodiphenyltrichlorethane into the spray programme for apples, Woolly Apple Aphis was controlled biologically. Dichlorodiphenyltrichloroethane has no effect on the Woolly Aphis but is toxic to its natural enemies with the result that in recent years this pest has been steadily increasing in importance. At present Woolly Aphis has to be controlled by chemical means, since the main parasite *Aphelinus mali* is only able to establish itself very late in the season, after damage has already been done.

Table 8: Efficacy of GUSATHION compared with METASYSTOX for the control of Bryobia mite (*Bryobia praetiosa* Koch)

Test Plants: Peach trees (Kakamas variety)
Layout of Test: One plot comprising 6 trees for each treatment
Method of Application: Power driven sprayer
Number of Applications: (1) METASYSTOX — 1 application on 13. 10. 1958
(2) GUSATHION (both concentrations) — 2 applications on 10. 10. 1958 and 13. 10. 1958

Number of adult Bryobia mites and immature stages per 20 leaves (average for 6 replicates per treatment) before application of treatments and on four occasions after treatment

Treatment per 100 gals. water	Pre-treatment		Post-treatment							
	9. 10. 58		21. 10. 58		29. 10. 58		7. 11. 58		25. 11. 58	
	Adults	Immature	Adults	Immature	Adults	Immature	Adults	Immature	Adults	Immature
GUSATHION 25% W. P. 1 lb. (0·025% a. i.)	397·67	—	0·00	18·00	0·00	83·00	0·0	1·00	0·0	2·83
GUSATHION 25% W. P. 2 lbs. (0·05% a. i.)	386·83	—	0·00	27·50	0·00	144·67	0·0	3·67	0·0	2·83
METASYSTOX 16 fl. ozs. (0·05% a. i.)	502·50	—	0·00	22·67	0·00	96·83	0·0	23·83	0·0	3·00
Control	442·50	—	0·00	32·00	0·67	198·00	111·50	151·50	258·50	41·50

Special summer sprays consisting of Parathion or METASYSTOX are recommended which would not be necessary if an insecticide recommended for Codling Moth would, at the same time, control Woolly Apple Aphis. For this reason, tests were carried out to determine what effect GUSATHION sprays, as applied for Codling Moth, would have on Woolly Apple Aphis. Results of these tests are expressed in Table 9. These results show that GUSATHION, as applied for Codling Moth control, will at the same time keep Woolly Apple Aphis at a low level, thus making special treatments unnecessary. It should be mentioned in this connection that GUSATHION, applied as a single treatment, cannot be considered as effective against Woolly Apple Aphis and is in fact far inferior to METASYSTOX which is customarily used for its control.

Table 9: Effect of 5 applications of GUSATHION at concentrations of 0·025 % and 0·05 % a.i. for the control of Codling Moth *(Cydia pomonella* L.) and Woolly Apple Aphis *(Eriosoma lanigerum* Hausm.)
Degree of infestation of Woolly Aphis: 0 = no infestation, 10 = heavy infestation.

No. of replicates	Preparathion per 100 gallons water			
	GUSATHION 1 lb. (0·025 % a.i.)	GUSATHION 2 lbs. (0·05 a.i.)	Dichlorodiphenyl-trichlorethane 2 lbs. (0·1 % a.i.)	Control
1	1	1	1	5
2	1	1	1	3
3	1	1	2	6
4	1	1	2	5
5	1	1	1	7
6	1	1	2	3
7	1	1	1	8
8	1	1	1	7
9	1	1	1	7
10	1	1	1	10
11	1	1	2	6
12	1	1	1	6
Total for 12 replicates	12	12	16	73
Average for 12 replicates	1	1	1·33	6·08

4. Leaf Rollers { *(Epichorista ionephela* Myr.) / *(Tortrix capensana* Wlk.)

Leaf Rollers in apples and pears in the Western Province have only in recent years gained importance. In previous years damage by the pest was either not noticed by growers, or not regarded as of any particular importance. At present, however, this pest can cause considerable damage, and insecticides are recommended for its control. Tests with GUSATHION (refer Table 10) have shown it also to be effective for control of Leaf Rollers at the concentration recommended for the control of Codling Moth.

Table 10: Efficacy of GUSATHION for the control of Leaf Rollers (*Epichorista ionephela* Myr. and *Tortrix capensana* Wlk.)
Test Plants: Pears
Layout of Test: Randomized blocks of 12 trees each; 6 replicates per treatment
Method of Application: Power driven sprayer, operating pressure 350 lbs. per sq. inch
Number of Applications: Five applications at intervals of about 3 weeks

Preparation	Total clean fruit	Damaged fruit	Total fruit harvested	% infestation	Total clean fruit	Damaged fruit	Total fruit harvested	% infestation
	Pears — Bon Cretien variety				Pears — Buerre Bosc. variety			
Methyl GUSATHION 1 lb. per 100 gals. water = 0.025% a. i.	2534	20	2554	0·78	3000	8	3008	0·62
Methyl GUSATHION ½ lb. per 100 gals. water = 0.0125% a. i.	3127	30	3157	0·95	2477	13	2490	0·52
Ethyl GUSATHION 1 lb. per 100 gals. water = 0.025% a. i.	2894	49	2943	1·66	3000	26	3026	0·85
Ethyl GUSATHION ½ lb. per 100 gals. water = 0.0125% a. i.	3060	60	3120	1·92	2206	24	2230	1·07
Control	3201	99	3300	3·0	3000	56	3056	1·83

Summary

GUSATHION (0,0-dimethyl-S-[benzaziminomethyl]-dithiophosphate) is used extensively for the control of several important insect pests which attack citrus and deciduous fruit in South Africa. The experimental work carried out with this preparation prior to its introduction as a pesticide are discussed. Details are

given of the fields of use of the product and the present recommendations. Experimental results are given, illustrating the efficacy of GUSATHION alone and in combination with Parathion for the control of *Aonidiella aurantii* (Mask.) and *Coccus hesperidum* L. on citrus. Brief information is also provided of the effect of GUSATHION against Aphis, Citrus Red Mite (*Metatetranychus citri* Mc. Gr.), Thrips and several scale insects. In the case of deciduous fruit, experimental data is presented, illustrating the efficacy of the product for control of *Cydia pomonella* L, *Bryobia praetiosa* Koch, *Eriosoma lanigerum* Hausm. and *Epichorista ionephela* Myr. or *Tortrix capensana* Wlk. Special reference is made to the development of a Red Spider strain resistant to phosphoric insecticides and the effect of GUSATHION on same.

Much of the experimental work with GUSATHION for the control of citrus pests was conducted by Mr. A. Busschots. Tests with the product for the control of pests occurring on deciduous fruit were carried out by our entomologists domiciled in the fruitgrowing areas of the Cape Western Province.

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Chemical control experiments on the Spiny Bollworm, *Earias insulana* Boisd., on cotton in Iraq 1956—1958

by
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Introduction

Nature of the Problem: The Spiny Bollworm, *Earias insulana* Boisd. *(Lepidoptera, Phalaenidae),* was first reported on cotton in Iraq by Thomas (1920). Rao reported in 1921 that the only bollworm found on cotton in Iraq was *E. insulana,* and that it attacked okra *(Hibiscus esculentus L.)* and certain malvaceous weeds.

The importance of this bollworm became increasingly greater with the expansion of cotton cultivation. In the absence of effective control methods, this pest was the chief hindrance to efforts aimed at increasing cotton production. During the 1950 and 1951 seasons, damage caused by this pest was estimated at 80 % of the cotton crop. As a result, the future of cotton cultivation was in jeopardy unless an effective control method was found quickly. All available materials were tested at the time without success. In 1952, Walker, on an assignment of the F. A. O., carried out trials that included, among other materials, the then very new insecticide Endrin, which proved to be superior to all other products.

However, another problem now arose, which assumed increasing economic importance. Through the use of Endrin, the red spider mite, *Tetranychus sp.,* possibly *T. bimaculatus* Harvey *(Acarina, Tetranychidae),* occurred in such great abundance that entire fields were menaced. Thus the spider mite problem was created, and gradually became of the same magnitude as the bollworm. Under such circumstances cotton growers were reluctant to have their fields sprayed with Endrin. A quick solution to the mite problem had to be found. Fortunately, SYSTOX® (and later METASYSTOX®) was marketed at that time. This product was included together with other materials in the trials beginning with the 1956 season. It proved to be superior to all other materials that were tested. On account of its systemic action it was always fully effective, even when coverage was not very thorough.

At a later stage in this series of trials, newer insecticides were brought to our notice, and when tested proved effective against the spiny bollworm (these tests will be described later on in this paper) but without stimulating spider mite spread.

Geographic Distribution: The spiny bollworm occurs as a pest of cotton in Australia, the Philippines, India, Spain, in a number of African countries, and throughout the Middle East.

® = Registered trade mark of Farbenfabriken Bayer Aktiengesellschaft, Leverkusen.

In Iraq, it is the number one pest of cotton, occurring in all the cotton-growing areas.

The red spider mite, *Tetranychus sp.*, occurs throughout most of the hot and dry regions of the world, attacking various host plants.

Spiny Bollworm Injury: Damage to cotton plants is caused by the larvae of *Earias insulana* which, early in the season, bore through the growing tips, thus stunting and causing malformation of the young plants. When the squares appear, they are attacked by the worm, and are so severely damaged that they drop. Later, as the bolls begin to develop, they become the target of bollworm attack, and the worms tunnel into them. A single worm can attack more than one boll during its lifetime, feeding upon the contents of the boll including the seeds. Damaged bolls are usually subject to a secondary attack by black fungi, such as *Aspergillus niger* Tiegh. and *Rhizopus nigricans* Ehr.

Besides cotton, the Spiny Bollworm has a number of other host plants which it attacks at various times of the year, as shown in the following summary:

Host plant		Time of year insect found on host
Common name	Scientific name	
Cotton	*Gossypium* spp.	May — Jan.
Deccan-hemp	*Hibiscus cannabinus* L.	Oct. — Nov.
Hollyhock	*Althaea rosea* L.	Dec. — May
Okra	*Hibiscus esculentus* L.	June — Jan.
Chinese hibiscus	*Hibiscus rosasinensis* L.	Dec. — May
Manchurian jute	*Abutilon theophrasti* Medic.	Sept. — Nov.

Until a few years ago, the spider mite had been of no economic importance as a pest of cotton in Iraq. But this has changed since the use of chlorinated hydrocarbons. Therefore, all insecticides found to be suitable for controlling spiny bollworm and which are intended to be used against this pest, must also be tested to establish whether they have a positive or negative influence on build-up of the spider mite population. For this reason development of the spider mite population was also kept under close observation in the trials described in this paper.

Summary of Previous Work

Trials on the chemical control of spiny bollworm in Iraq were begun in 1951 (Meymarian), with BHC and DDT, but without success. The following materials were tested one year later, also without success:

Cotton dust 3:10:0 (3% BHC, 10% dichlorodiphenyltrichloroethane and 0% sulphur)
Dichlorodiphenyltrichloroethane 10% dust

Dichlorodiphenyltrichloroethane 25 % liquid
BHC dust (2·6 % gamma isomer)
BHC liquid (9 % gamma isomer).

In the same year, Walker also carried out experiments with a number of newer chlorinated hydrocarbons of which Endrin was the most effective. During the following year, Haidari (unpublished) repeated the trials confirming the results of the previous season. The following is a summary of the findings of Walker and Haidari:

1. Endrin Emulsion, used at a rate of 142—284 gr. of active ingredient per donum*, was the most effective material used.
2. The other materials tested were far less effective.
3. It was recommended that spraying should be carried out as soon as the infestation in the field approaches the 10 per cent level, and that treatments should be repeated whenever the newly injured boll count rises again to 10 %. Alternatively, the application should be repeated every 10 days regardless of the percentage of infestation.
4. When a severe infestation is anticipated, the earlier the application of insecticide the better.
5. There was no significant difference between 4 and 6 applications during the season.
6. There were strong indications of a large build-up of the red spider mite population in the fields following application of Endrin, for which case a sulphur dust treatment was recommended as an additional measure.

Preliminary Trials with Newer Materials in 1956 and 1957

Preliminary trials were carried out in 1956 and 1957 with the object of establishing how newer insecticides, assumed not to encourage build-up of the spider mite population, compared with Endrin in controlling spiny bollworm.

All these trials were conducted in randomized blocks where each treatment, including the check plots, was replicated four times. The following results were obtained:

1. It was found that GUSATHION®, at the rate of 284 gr. of active ingredient per donum, was the most effective among the materials used in these trial controls of spiny bollworm, and that at this rate it was more effective than Endrin applied at a rate of 172 gr. of active ingredient per donum. But GUSATHION was less effective when applied at rates of 142, 200 and 220 gr. of active ingredient per donum.

   DIPTEREX®, applied at rates of 142, 284, 312, 353 and 367 gr. of active ingredient per donum, gave inconsistent results. Some were similar to those of Endrin, others were slightly better.

   All other materials tested (Toxaphene, CHLORTHION® and DICONTAL®) failed to give satisfactory results.

* donum = 2,500 square metres.

2. In the trials in which Endrin (at a rate of 172 gr. of active ingredient per donum) was tested in combination with acaricides, only the combination with METASYSTOX (172 gr. of active ingredient per donum) gave excellent control, while all other combinations were not satisfactory.

Trials in 1958

Objective: These trials were conducted at the Abu-Ghraib Experiment Station, some 20 kilometres north-west of Baghdad. Two experiments were carried out, differing only in the size of plots and timing of application. The materials used in these experiments were those found to be effective in the preliminary trials discussed on the previous pages. The object was to confirm previous findings, ascertain the most economical dosages, and number and timing of applications.

Methods and materials: The experiments were conducted in randomized blocks, each treatment being replicated six times. In the first experiment, the size of each plot was 132 square metres, containing an average of 684 cotton plants, while in the second experiment the size of each plot was 160 square metres with an average of 816 plants.

The cotton plants in all the experimental plots were planted in rows, and growth developed normally during the time of the trials. Ordinary compressed-air knapsack sprayers (Mysto) fitted with two nozzles were used. Pressure was maintained as far as practicable at about sixty pounds per square inch.

Spraying was always started in the early hours of the morning. In the first experiment, the first spray application was carried out when spiny boll-

Table of applied materials

Name of product	Active ingredient	Formulation
Endrin	Hexachloroepoxyoctahydro-[bis-(endo-endo)-methylene]-naphthalene	19·5 % E. C.
GUSATHION	0,0-dimethyl-S-(4-oxybenzo-1,2,3-triazinyl-3-methyl)-dithiophosphate	20 % E. C.
DIPTEREX	0,0-dimethyl-trichloro-oxyethyl-phosphonate	50 % E. C.
METASYSTOX	0,0-dimethyl-0-(and-S-)-(2-ethylmercaptoethyl)-thiophosphate	50 % E. C.

E. C. = Emulsifiable concentrate

worm infestation in the fields averaged about 7 %, and the treatment was repeated 20 days later (for dates of other treatments, see Table 2).

In the second experiment, the control was started when the average infestation in the field plots was 10 %, and the treatments repeated whenever infestation rose again to 10 %.

The following materials were included in the experiments:

Table No. 1: Experiment No. 1
Effectiveness of GUSATHION, DIPTEREX and Endrin + METASYSTOX against *Earias insulana* Boisd. on cotton
Abu-Ghraib Experiment Station, Iraq — 1958

Product	gr. active ingredient/ donum*	% reduction of *E. insulana* infestation as against untreated check			% increase over the check in yield of cotton		
		prior to 1st. picking	prior to 2nd. picking	total	1st. picking	2nd. picking	total
GUSATHION	284	79	78	79	34	46	36
DIPTEREX	284	69	67	68	27	18	25
Endrin + METASYSTOX	172 172	67	62	65	24	10	22

* The donum is 2,500 square metres

Evaluation of experiments:

25 squares or bolls were picked each week at random from the two diagonals of each test plot, and counts were made of the number of *Earias insulana* larvae on the sampled squares or bolls.

Spider mite infestation was also recorded.

Cotton lint was hand-picked, weighed separately for each plot, and recorded.

The following tables give the results obtained in the trial controls of *Earias insulana.*

Table No. 2: Summary of all counts made in Experiment No. 1
Effectiveness of GUSATHION, DIPTEREX and Endrin + METASYSTOX against *Earias insulana* Boisd. on cotton
Abu-Ghraib Experiment Station, Iraq — 1958

Product	gr. active ingredient/ donum [1])	Average green boll infestation by *E. insulana* [2])			Average yield of cotton per donum in kilos [3])		
		prior to 1st. picking	prior to 2nd. picking	total	1st. picking	2nd. picking	total
GUSATHION	284	2.833	2.000	4.833	301.919	56.817	358.736
DIPTEREX	284	4.166	3.000	7.166	285.189	45.769	330.958
Endrin + METASYSTOX	172 172	4.500	3.500	8.000	280.455	42.928	323.383
Check	—	13.500	9.166	22.666	225.216	38.825	264.041
Analysis of variance: L. S. D.							
5% level:		1.937	1.784	2.687	16.123	10.248	17.498
1% level:		2.678	2.467	3.716	22.297	14.172	24.198

Note:

1) Six applications:
Prior to 1st. picking:
4 applications on May 27, June 16, July 10, July 29.
Prior to 2nd. picking:
2 applications on August 16 and September 10.

2) Average of four counts:
3 prior to 1st. picking — on July 8, July 26 and August 10.
1 prior to 2nd. picking — on September 28.
Total no. of green bolls counted for each product = 600.

3) 1st. picking on August 13.
2nd. picking on November 10.

Table No. 3: Experiment No. 2
Effectiveness of GUSATHION, DIPTEREX and Endrin + METASYSTOX against *Earias insulana* Boisd. on cotton
Abu-Ghraib Experiment Station, Iraq — 1958

Product	gr. active ingredient/ donum	% reduction of *E. insulana* infestation as against untreated check	% increase over the check in yield of cotton		
			1st. picking	2nd. picking	total
GUSATHION	284	71	37	57	38
DIPTEREX	284	69	26	42	27
Endrin + METASYSTOX	172 172	60	17	8	17

Table No. 4: Summary of all counts made in Experiment No. 2
Effectiveness of GUSATHION, DIPTEREX and Endrin + METASYSTOX against *Earias insulana* Boisd. on cotton
Abu-Ghraib Experiment Station, Iraq — 1958

Product	gr. active ingredient/ donum [1])	Average green boll infestation by *E. insulana* [2])	Average yield of cotton per donum in kilos [3])		
			1st. picking	2nd. picking	total
GUSATHION	284	7.500	433.594	24.088	457.682
DIPTEREX	284	8.000	399.479	21.875	421.354
Endrin + METASYSTOX	172 172	10.500	370.573	61.666	387.239
Check	—	26.166	315.625	15.364	330.989

Analysis of variance: L. S. D.

5% level:	4.709	26.537	2.887	25.188
1% level:	6.512	36.699	3.993	34.833

Note:

1) Four applications on July 5, July 30, August 18, September 10.

2) Average of 3 counts: on July 23, August 11 and August 26.
Total no. of green bolls counted for each product = 450.

3) 1st. picking on August 8.
2nd. picking on November 12.

Summary of Results

1. In the trials described in this paper, the results obtained confirmed that GUSATHION controls *Earias insulana* more effectively than the previously used insecticides. The following table lists the insecticides applied in these trials in their order of effectiveness against spiny bollworm.

Product	gr. active ingredient/donum	% reduction of green bolls damaged by *Earias insulana* as against untreated check
GUSATHION	284	71—79
DIPTEREX	284	69
Endrin + METASYSTOX	172 172	60—67

2. The application of GUSATHION, DIPTEREX and Endrin + METASYSTOX brought about a reduction of the spider mite population as compared with the untreated plot. The best effect in this respect was obtained by the addition of METASYSTOX.

3. As far as the cotton yield is concerned, plots treated with GUSATHION gave the highest yield, those treated with DIPTEREX were second, while plots treated with Endrin + METASYSTOX were in third place, as the following figures indicate:

Product	% increase over the check in cotton yield
GUSATHION	36—38
DIPTEREX	25—27
Endrin + METASYSTOX	17—22

4. There was no significant difference between four and six treatments during the season for any of the materials used, as the results of the two experiments show.

5. Observations showed that early application of the insecticide, i. e. when spiny bollworm infestation in the field averages no higher than 7 to 10 %, is essential for best results. The treatment must be repeated whenever the infestation rises once more to about 10 % in the newly developed squares and bolls. Alternatively, when it is inconvenient to calculate infestation percentages, the treatment will have to be repeated every 14 to 20 days, according to whether the infestation is expected to be slight or severe.
6. When Endrin is used for controlling spiny bollworm, an acaricide must be added to it to prevent build-up of the spider mite population. METASYSTOX (at a rate of 100—172 gr.* of active ingredient per donum) proved to be a most suitable acaricide in these trials.
7. Another experiment showed that the combination of 142 gr. of GUSATHION active ingredient + 426 gr. of dichlorodiphenyltrichloroethane active ingredient per donum was not so effective as the application of GUSATHION alone at a rate of 284 gr. active ingredient per donum.
8. All other tested insecticides were ineffective against spiny bollworm.

Conclusions and Recommendations

While Endrin was the first product to give satisfactory chemical control of Spiny Bollworm, its wide use, however, in cottonfields in Iraq gave rise to still another problem of equal importance, namely resurgence or heavy multiplication of *Tetranychus* spec. Mixing of acaricides with Endrin to prevent spider mite build-up meant additional cost. Therefore, newer insecticides were tested in order to find a solution to both problems.

The results of three-season trials in 1956, 1957 and 1958 convinced us that GUSATHION gives good control of Spiny Bollworm, prevents build-up of spider mite and especially brings about a higher yield of cotton.

Of the insecticides tested, DIPTEREX takes second place after GUSATHION.

Endrin, when mixed with the necessary amount of METASYSTOX gives good control of *Tetranychus* spec. regardless of how high the initial spider mite population might be, but this mixture is less effective against spiny bollworm than the two above-mentioned products and also results in a lower yield of cotton than either GUSATHION or DIPTEREX.

Therefore, we recommend:

1. The use of GUSATHION at a rate of 284 gr. of active ingredient per donum.
2. The use of DIPTEREX at a rate of 284 gr. of active ingredient per donum.
3. When Endrin is used (at a rate of 172 gr. of active ingredient per donum), add an equal quantity of METASYSTOX active ingredient.

The first treatment must be carried out as soon as the average infestation in the fields approaches 10 %. A higher dosage may be necessary if the initial infestation is higher than 10 %.

* Lower dosage for preventive treatment, higher dosage level for eradicative application.

Thorough coverage of the plants during the spraying operation is of utmost importance to guarantee good results, except in the case of METASYSTOX which always gives excellent results on account of its systemic action also when plants are not wetted so copiously with this product.

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